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The Hydrostatic Trough.

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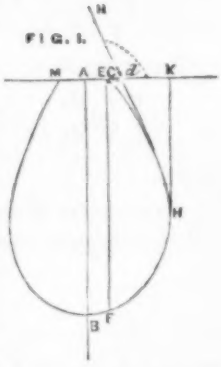
Problem.—If a perfectly flexible and inextensible trough have its edges firmly fixed in a horizontal plane, and filled with a heavy fluid, it is required to find the equation of a transverse section.

Or, the problem may be stated in the following way:

If a perfectly flexible and inextensible arc, MBC, Fig. 1, be fixed at its ends, M and C, and filled with a heavy fluid; it is required to find its form under the pressure of the fluid. This I call "A Hydrostatic Trough," in distinction from the "Hydrostatic Arch" of Von Villarceaux.

FIG. 1.



The problem which I have proposed is that of a normally pressed arc. But few problems of such curves have, to my knowledge, ever been solved. The first one is very simple, being that of a ring placed horizontally under a fluid, in which case the curve is a circle; the second is the "Hydrostatic Arch" of Von Villarceaux, in which the arch is placed

under a fluid so that the crown will be at a finite distance from the surface of the fluid. The third was investigated for a suspension bridge, by Mr. Robinson, and is published in the September Number of this Journal for 1863. In the following article I shall investigate the fourth one.

I will first investigate the general equations applicable to normally pressed arcs.

Let $f(x,y,z,)$ be the equation of the curve referred to rectangular co-ordinates,

T, the tension at any point,

X,Y,Z, the components of the impressed forces on a unit of length of the curve,

ds an element of the arc.

Then, Xds, Yds, Zds, are the components on an element of length.

$T\frac{dx}{ds}$ is the component of T on the axis of x, and

$d\left(T\frac{dx}{ds}\right)$ is the component of the tension on ds due to the impressed forces on the element, consequently equal Xds; similarly for the others.

$$\therefore \quad \left.\begin{aligned} d\left(T\frac{dx}{ds}\right) &= Xds \\ d\left(T\frac{dy}{ds}\right) &= Yds \\ d\left(T\frac{dz}{ds}\right) &= Zds \end{aligned}\right\} \quad \ldots \quad (1)$$

These equations are applicable to any curve in which the forces are continuous functions of the co-ordinates. But in a normally pressed arc T *is constant;* for it cannot vary unless there be a tangential component of the applied forces; but there can be no tangential component when they are all normal.

Observing this, squaring and adding, and we have

$$T^2\left[\left(d\frac{dx}{ds}\right)^2+\left(d\frac{dy}{ds}\right)^2+\left(d\frac{dz}{ds}\right)^2\right]=(X^2+Y^2+Z^2)\,ds^2 \quad . \quad (2)$$

Let

ρ = radius of curvature at point, $(x,y,z,)$

P = applied force on a unit of length, and equation (2) becomes

$$T^2\rho^2\,ds^2=P^2\,ds^2;$$

$$\therefore P=\frac{T}{\rho}. \quad \ldots \quad (3)$$

Hence, the applied force on each unit of length will be inversely as the radius of curvature.

In Fig. 1, let

D = AB = total depth of the trough,
$\rho_\circ$ = the radius of curvature at the lowest point,
i = angle Ndk which the tangent at any point makes with the axis x,
$i_\circ$ = the value of i at the superior element,
w = weight of unit of volume of the fluid.

Take the origin at A, the middle point of the span; x horizontal, and y vertical.

Since the pressure of a fluid is proportional to its depth, we have

P = wy; hence from (3) we have
T = $wy\rho$ for any point, and
T = $w\mathrm{D}\rho_\circ$ for the lowest point.

$$\therefore \quad wy\rho = w\mathrm{D}\rho_\circ. \qquad (4)$$

$$\therefore \quad \text{or } \rho = \frac{\mathrm{D}\rho_\circ}{y}, \qquad (5)$$

Hence the radius of curvature at any point is inversely as the distance of the point below the surface of the fluid; hence at the upper end it is infinite.

The second member of (4) is constant; hence it is the equation of an hyperbola referred to its asymptotes, in which ρ is the abscissa and y the corresponding ordinate.

Substituting the value of the radius of curvature in (5), and we have

$$\pm\left(1+\frac{dy^2}{dx^2}\right)^{-\frac{3}{2}}\frac{d^2y}{dx^2} = \frac{y}{\mathrm{D}\rho_\circ}.$$

The first integral is

$$\mp\left(1+\frac{dy^2}{dx^2}\right)^{-\frac{1}{2}} = \frac{y^2}{2\mathrm{D}\rho_\circ} + \mathrm{C} \qquad (6)$$

In the second integral I find that the *minus* sign before the parenthesis gives an imaginary result; hence we use the plus sign only.

Observing that $\frac{dy}{dx} = 0$ for $y = \mathrm{D}$, and (6) gives

$$\mathrm{C} = 1 - \frac{\mathrm{D}}{2\rho_\circ} = \frac{2\rho_\circ - \mathrm{D}}{2\rho_\circ}.$$

$$\therefore \left(1+\frac{dy^2}{dx^2}\right)^{-1} = \frac{y^2}{2\mathrm{D}\rho_\circ} + \frac{2\rho_\circ - \mathrm{D}}{2\rho_\circ}. \qquad (7)$$

For $y = 0$, $i = i_\circ$ and $\left(1+\frac{dy^2}{dx^2}\right)^{-\frac{1}{2}} = \cos.\ i_\circ$.

$$\therefore \cos.\ i_\circ = \frac{2\rho_\circ - \mathrm{D}}{2\rho_\circ} = 1 - \frac{\mathrm{D}}{2\rho_\circ}. \qquad (8)$$

$$\therefore \rho_\circ = \frac{\frac{1}{2}\mathrm{D}}{1 - \cos.\ i_\circ} = \frac{\mathrm{D}}{4\sin^2\frac{1}{2}i_\circ}. \qquad (9)$$

Hence if $i_\circ = 0$, $\rho_\circ = \infty$
$i_\circ = 90°$, $\rho_\circ = \frac{1}{2}$ D
$i_\circ = 180°$, $\rho_\circ = \frac{1}{4}$ D
$i_\circ > 90°$, $\rho_\circ < \frac{1}{2}$ D
$i_\circ < 90°$, $\rho_\circ > \frac{1}{2}$ D

$\rho_\circ = \frac{1}{4}$ D is the limit of $\rho_\circ$ in the direction of its smallest value, but a limit it can never reach unless T is infinite; for the vertical component of T at the upper end must sustain one-half the fluid; or

$$w \int_\circ x\, dy = \text{T} \sin. i_\circ. \quad . \quad . \quad . \quad (10)$$

but for $i_\circ = 180°$, sin. $i_\circ = 0$ $\therefore$ T must be infinite if the first number is finite.

Some of the preceding expressions may be deduced in a more elementary way: thus, the total horizontal pressure of the fluid must equal the tension at the lowest point, together with the horizontal component at the upper end; or more generally, the horizontal components in one direction must equal those in the opposite direction. The horizontal pressure of the fluid is $\frac{1}{2} w \text{D}^2$: the horizontal component of the tension at the upper end is T cos. $i_\circ$, and is negative when the angle is obtuse. We have then

$$\frac{1}{2} w \text{D}^2 = \text{T} - \text{T} \cos. i_\circ.$$

$$\therefore \text{T} = \frac{\frac{1}{2} w \text{D}^2}{1 - \cos. i_\circ}. \quad . \quad . \quad . \quad (11)$$

Let $y_1 = \text{KH} =$ the vertical tangent ordinate.

The horizontal pressure between y_1 and D equals the tension at the lowest point.

$$\therefore \frac{1}{2} w (\text{D}^2 - y_1^2) = \text{T} = w \text{D} \rho_\circ. \quad . \quad . \quad (12)$$

$$\therefore y_1 = \sqrt{\text{D}^2 - 2\,\text{D}\,\rho_\circ}. \quad . \quad . \quad . \quad (13)$$

Eliminating between (11), (12), and (13), and we find,

$$\rho_\circ = \frac{\frac{1}{2}\text{D}}{1 - \cos. i_\circ}$$ which is the same as (9).

If $i_\circ = 90°$ Equation (11) gives $\text{T} = \frac{1}{2} w \text{D}^2$
and " (9) " $\rho_\circ = \frac{1}{2}$ D, and this
in " (13) " $y_1 = 0$, and this
in " (12) " $\text{T} = \frac{1}{2} w \text{D}^2$ as before.

If $i_\circ$ is less than 90°, we have

$$\frac{1}{2} w \text{D}^2 + \text{T} \cos. i_\circ = \text{T}.$$

$$\therefore \text{T} = \frac{\frac{1}{2} w \text{D}^2}{1 - \cos. i_\circ}$$ which is the same as (11).

Now returning the differential expression we observe that (6) gives

$$(dx^2 + dy^2)^{\frac{1}{2}} = ds = \frac{2\,\rho_\circ\,\text{D}\,dy}{\sqrt{4\,\text{D}^2\rho_\circ^2 - (2\,\text{D}\rho_\circ\,\text{C} + y^2)^2}} \quad (14)$$

or $$dx = \frac{2\,\text{D}\,\rho_\circ\,\text{C} + y^2}{\sqrt{4\,\text{D}^2\,\rho_\circ^2 - (2\,\text{D}\,\rho_\circ\,\text{C} + y^2)^2}} dy. \quad . \quad (15)$$

To find where x is a maximum, make $\frac{ds}{dy}=1$ in (14) or $\frac{dx}{dy}=0$ in (12); in either case we find

$y=y_1=\sqrt{D(-2\rho_\circ+D,)}$ which is the same as (13).

Equations (14) and (15) may be integrated by means of elliptic functions. Substitute the value of c and make *

$$c^2=\frac{D}{4\rho_\circ}=\sin^2.\ \theta\ \therefore \sin.\ \theta=\tfrac{1}{2}\sqrt{\frac{D}{\rho_\circ}}. \quad . \quad . \quad (16)$$

$$y=D\cos.\ \varphi\ \therefore\ dy=-D\sin.\ \varphi d\varphi. \quad . \quad . \quad (17)$$

These in (14) give

$$s=\int\frac{-2\rho_\circ D^2\sin.\ \varphi d\varphi}{\sqrt{D^2\rho_\circ{}^2-(2D\rho_\circ-D^2+D^2\cos.^2\varphi)^2}}$$

Make $\cos.^2\varphi=1-\sin.^2\varphi$, develop and reduce, and we find

$$s=\int\sqrt{\frac{-2\rho_\circ D^2\sin.\ \varphi d\varphi}{4\rho_\circ D^3(1-\frac{D}{4\rho_\circ}\sin.^2\varphi)\sin.^2\varphi}}$$

$$=\sqrt{\rho_\circ D}\int_\circ^\varphi\frac{-d\varphi}{\sqrt{1-c^2\sin.^2\varphi}}. \quad . \quad . \quad (18)$$

The substitutions in (15) will give

$$x=\int\frac{-[D(2\rho_\circ-D)+D\cos.^2\varphi]\,d\varphi}{2\sqrt{\rho_\circ D}\sqrt{1-\frac{D}{4\rho_\circ}\sin.^2\varphi}}$$

$$=-2\sqrt{\rho_\circ D}\left[\frac{\frac{1}{2}-\frac{D}{4\rho_\circ}\sin.^2\varphi}{\sqrt{1-\frac{D}{4\rho_\circ}\sin.^2\varphi}}\right]d\varphi$$

By adding and subtracting 1 to the numerator, it may be put under the following form, viz:

$$x=-2\sqrt{\rho_\circ D}\left[-\tfrac{1}{2}\int_\circ^\phi\frac{d\phi}{\sqrt{1-c^2\sin.^2\phi}}+\int_\circ^\phi(1-c^2\sin.^2\varphi)d\varphi\right] \quad (19)$$

The complete integral of (18) is

$$s=\sqrt{\rho_\circ D}\,F_{1(c)}. \quad . \quad . \quad . \quad . \quad (20)$$

The general integral of (19) is

$$x=2\sqrt{\rho_\circ D}\left[-\tfrac{1}{2}F_{(c,\phi)}+E_{(c,\phi)}\right] \quad . \quad (21)$$

in which we compute the arc from the lowest joint. I have changed the sign of x, for the curve is symmetrical with the axis y; and hence the positive value will equal the negative one.

* See Legendre's Fonctions Elliptique, Chap. III.

For the half span AC, we have from (17) and (21

$$y=0,\ \therefore \varphi=90^\circ$$

$$x=x_\circ=2\sqrt{\rho_\circ \mathrm{D}}\left[-\tfrac{1}{2}\mathrm{F}_{1(c)}+\mathrm{E}_{1(c)}\right]. \qquad (22)$$

Equation (21) is the equation of the curve, and by means of it and (17) it may be constructed. We see that the *form* is independent of the weight of the fluid.

In problems of this kind the data would naturally be the length of arc and span, but with such data the problem can only be solved by successive approximations; for c, which is a function of D in (21), cannot be found explicitly. But if D and $\rho_\circ$ are known we may obtain a direct solution.

For example, let $\rho_\circ = \frac{16}{49}\mathrm{D}$.

Then from (16) $c=\sin.\theta=\frac{7}{8}$ $\therefore\ \theta=61^\circ\ 3'$.

In the second volume of Legendre's *Fonctions Elliptique*, Table VIII, we find for $\theta=61\frac{01}{20}$ that $\mathrm{F}_{1(c)}=2{\cdot}18566$.

Hence the total length is

$$2s=2\sqrt{\frac{16}{49}\mathrm{D}^2}\times 2{\cdot}18566=2{\cdot}52912\ \mathrm{D}.$$

From the same table we find

$$\mathrm{E}_1\left(61\tfrac{01}{20}\right)=1{\cdot}20106.$$

Then (20) gives $2x=6{\cdot}2474$ D . . (23)
for the total span at the upper end.

To construct the curve, we will call $\theta=61^\circ$. From equations (21) and (17) and Table IX, we find

for	φ	$=$	0°	y	$=$	$1{\cdot}000$ D	x	$=$	$0{\cdot}000$
	φ	$=$	20°	y	$=$	$0{\cdot}940$ D	x	$=$	$0{\cdot}190$ D
	φ	$=$	40°	y	$=$	$0{\cdot}766$ D	x	$=$	$0{\cdot}325$ D
	φ	$=$	50°	y	$=$	$0{\cdot}643$ D	x	$=$	$0{\cdot}354$ D
	φ	$=$	53°	y	$=$	$0{\cdot}602$ D	x	$=$	$0{\cdot}357$ D
	φ	$=$	54°	y	$=$	$0{\cdot}587$ D	x	$=$	$0{\cdot}361$ D
	φ	$=$	55°	y	$=$	$0{\cdot}574$ D	x	$=$	$0{\cdot}360$ D
	φ	$=$	70°	y	$=$	$0{\cdot}342$ D	x	$=$	$0{\cdot}308$ D
	φ	$=$	90°	y	$=$	$0{\cdot}000$ D	x	$=$	$0{\cdot}125$ D

By means of these values, I have constructed Fig. 1.

For the maximum abscissa we have from (13) $y_1=\frac{1}{4}\mathrm{D}\sqrt{17}=0{\cdot}5890\ \mathrm{D}$, which in (17) gives $\varphi=53^\circ\ 54'$, which agrees well with the table above. This value of φ in (21) will give x.

For the inclination at the upper end we have from (8), $i_\circ=111^\circ\ 18'$.

For the tension, (4) gives $\mathrm{T}=\frac{16}{49}w\mathrm{D}^2$.

For the total weight of the fluid, we have $2\,\mathrm{T}\sin. i_\circ = \frac{32}{49} w\,\mathrm{D}^3 \times 0{\cdot}93789$; hence the total area of the curve is $\frac{32}{49}\mathrm{D}^5 \times 0{\cdot}93789$.

Fig. 2 is the curve when the upper ends are vertical.

FIG. 2.

Suppose $\rho^\circ = \frac{1}{4}\,\mathrm{D}$; then we will have $\varphi = 90°$, and this in (21) gives $x = -\infty$; hence the axis of x is an asymptote to the curve, as shown in Fig. 3.

FIG. 3.

To find $\rho_\circ$ when the upper ends terminate in the origin. For this x and y are zero, and (21) gives

$$\tfrac{1}{2}\mathrm{F}_{1(c.)} = \mathrm{E}_{1(c.)}$$

from which c must be found. Table VIII, in Legendre, gives $c = \sin. 65°\ 18'$ nearly, and observing that $c = \frac{1}{2}\sqrt{\frac{\mathrm{D}}{\rho_\circ}}$ and we find

$$\rho_\circ = 0{\cdot}303\,\mathrm{D} \text{ nearly.}$$

To find the evolute of the curve.

Let x, and y, be the co-ordinates of the evolute. Then we readily find

$$-x_1 = -x + \rho \sin. i.$$
$$y_1 = y - \rho \cos. i.$$

which combined with the preceding equations so as to eliminate x, y, ρ, and i, will give the equation of the evolute.

The question naturally arises whether this principle is applicable to shells filled with a fluid, and if so it may give important information on the construction of jugs and bottles. Conceive a shell to be generated by the revolution of one of these curves about the axis of y: the shell generated will be of uniform thickness. Now, intersect this shell with a plane through the axis of y, and examine the pressure along this intersection. We at once see that the pressure is greatest at the lowest point, but the thickness is uniform and hence does not fulfill the conditions.

If we suppose that the total resisting surface in all horizontal intersecting planes in the same, we meet with a similar difficulty, for then the shell would be thinner (if in the form of a jug) below the middle of the depth than at the top, but the pressure would be greater at the latter than at the former point. In the case of bottles we must consider the strain in different planes; hence our investigation gives no light upon their proper construction.

In the early part of this article I intimated that but few curves of normally pressed arcs have been investigated; but it may be well to add that if a string be drawn upon (or around) a perfectly smooth curved surface the tension will be constant and the pressure normal;

but in this case the curve is known *à priori*. Such curves are called *Geodesic*, and their form depends upon that of the surface about which they are drawn.

The Actual State of the Works on the Mont Cenis Tunnel, and Description of the Machinery Employed. By THOMAS SOPWITH, JR.

From the Lond. Civ. Eng. and Arch. Jour., March, 1864.

This tunnel would form the completing link of the Victor Emmanuel Railway, and be the means of putting France and Italy in direct railway communication. The railway on the French side was already opened to St. Michael in Savoy, and on the Italian side to Susa in Piedmont. When the whole line was completed the mails and traffic with India might perhaps be advantageously transferred from Marseilles to some Italian port, as the Mediterranean Sea transit would thus be materially shortened.

During the last twenty years, many routes had been surveyed and recommended for crossing the great barrier of the Alps. Of these, that by the Mont Cenis was generally considered the most feasible; and that it was only a question, whether the mountain should be crossed by a series of inclines, or whether a tunnel should be made. In 1857, Messrs. Sommeiller, Grandis, and Grattoni, brought before public notice a new system of boring by machinery, instead of by hand labor. A government commission was appointed to report upon it, and to see if it could be applied to the boring of the tunnel under Mont Cenis. Their report was favorable, and M. Sommeiller and his partners were shortly afterwards charged with the execution of the work.

The ends only were available for attack, it being impossible, as was known from the first to sink shafts. It was feared that the ventilation would seriously retard, or altogether prevent, the completion of the tunnel; but this fear was uncalled for, as the artificial ventilation of collieries overcame greater natural difficulties, and the ventilating current passed through a longer distance, than could possibly be required in this tunnel. M. Sommeiller also proposed to use compressed air for driving the machinery, and calculated that on its escape, a volume of fresh air would be supplied adequate to the requirements of the workmen. The tunnel at the Modane, or French side, was of the following dimensions:—25 ft. 3½ ins. wide at the base, 26 ft. 2¾ ins. wide at the broadest part, and 24 ft. 7 ins. in height; the arch being a semicircle nearly. At Bardonnèche, the height was increased 11¾ inches. The exact length between the ends was 7·5932 miles. The present ends would not be the permanent entrances, as it was intended that a curved gallery should leave the tunnel at the north side, 415 yards from the end, and at the south side, 277 yards.

At Modane, the tunnel, was built entirely with stone; at Bardonnéche, for the greater part, the side walls only were of stone, and the remainder of brick. The Bardonnèche end was 434 feet higher than that at Modane. For one-half the length of the tunnel, therefore, from Modane to the middle, the gradient would be 1 in 45½; the other side

being driven with only sufficient fall, 1 in 2000, to allow of the water escaping.

When the tunnel was complete, it was expected that there would be a constant current of air from the north to the south; the latter was not only the higher end, but the air was more rarified and exposed to the heat of the sun, whilst the entrance at Modane, was under the shade of the mountain.

The establishment consisted at each end, of machinery for compressing the air, workshops for making and repairing the machinery, offices, storehouses, residences for the engineers, and barracks for the workmen. At Modane, the entrance of the tunnel was 328 feet above the bottom of the valley, where the workshops were placed, with which there was a communication by means of an inclined plane, worked by a water balance.

Different systems of tunneling by machinery had been tried in England; amongst others one by Captain Penrice, R. E., in which it was intended to drive a gallery about 4½ feet diameter, and, by means of repeated blows from a heavy frame loaded with knives, to reduce the whole of the excavated materials to small chippings and dust. It seemed, however, to the author, that any system of tunneling must be deficient, which did not make so cheap and readily applicable a power as gunpowder available; and that by the trituration of the rock to such small particles as in Captain Penrice's system, a great amount of work was unnecessarily performed.

In M. Sommeiller's system, whilst machinery was employed for accelerating the progress usually made by hand labor, gunpowder was also available. He had succeeded in producing a compact machine, not weighing more than 6 cwt., which could pierce a common bore-hole, about 1¼ ins. diameter, and 3 feet deep, into a rock in twenty minutes, where two miners would have required two hours. Further, he had arranged a movable support capable of carrying eleven such machines, any one of which could be worked at almost any angle, and of allowing the free action of each, in a gallery 10 feet square. This support could be removed when it was necessary to explode the holes bored by the machines. The machine was of very ingenious construction. It consisted of two parts:—one, a cylinder for propelling the borer against the rock; the second, a rotary engine for working the valve of the striking cylinder, turning the borer on its axis at each successive stroke, and advancing, or retiring, the striking cylinder as occasion required. It gave 250 blows per minute. The effective pressure on the piston in striking was 216 lbs.; the length of the stroke was from 2 inches to 7½ inches. Although simplified as much as possible, the nature of the work the machines performed was so severe, that they were liable to frequent derangement, and a large stock was kept on hand. The cost of each machine was about £80. The compressed air was used at a pressure of five atmospheres above atmospheric pressure, and was conveyed to the "fore-head" of the advanced gallery by a pipe 7⅞ inches diameter. The advanced gallery was the only place

where the machines were used; the enlarging of the tunnel to the full size, walling, &c., were performed by manual labor.

The system of working was to bore about eighty holes in the fore-head of the advanced gallery. The frame and machines were then withdrawn, and a set of men charged and fired the holes; afterwards replaced by another set to remove the déblais. The division of time amongst the different classes of labor was very variable. It might however, be averaged as

From 6 to 8 hours for the machinists,
" 1½ " 2 " for charging and firing, and
" 3 " 5 " for removing the déblais.

Thus there were almost two complete shifts every twenty-four hours. An alignment was made about once in three months, from an observatory at each end. As yet no error had been detected.

Three or four large holes, each about 4 inches diameter, were bored near the centre of the fore-head. These were not charged and exploded, their purpose being to weaken the surrounding rock. The remainder were charged, those adjoining the centre being first fired, and the result of these explosions was a cavity. The remaining holes were then exploded from this cavity outwards.

The workmen were industrious under circumstances which required more than ordinary perseverance. A premium on their wages was given for more than a certain advancement per day. At the time of the author's visit, one metre per day was the standard. For a progress of

$1\frac{1}{10}$	metre per day	$1\frac{1}{10}$	day's wages was paid.
$1\frac{2}{10}$	" " "	$1\frac{2}{10}$	" " "
$1\frac{3}{10}$	" " "	$1\frac{3}{10}$	" " "
$1\frac{4}{10}$	" " "	$1\frac{4}{10}$	" " "

This scale was subject to adjustment every fortnight.

The déblais resulting from the explosion of the eighty holes was removed in small wagons. Its removal was well organized, and considering the circumstances, quickly effected. It would be much accelerated, if it was possible to construct an iron frame, strong enough to be placed close to the fore-head at the time of the explosion, and receive without injury the products of explosion, which could be removed *en masse*, or nearly so.

Two descriptions of machines for compressing air were in use,—one on the hydraulic ram principle, the other resembling a pump. In the first, the water was admitted, with a pressure of 85¼ feet, into a column or vessel, containing air, about 14 feet high and 2 feet in diameter. The water by its momentum rushed up the column, compressed the volume of air, and forced it through a valve into a reservoir. The pressure valve being closed, the exhaust valve was opened and the water fell in the column at the same time, its place was taken by air, and the machine became ready for another stroke. This machine made 2½ strokes per minute, and was capable of supplying about 20 cubic feet of air, compressed to five atmospheres per minute. The other machine consisted of a horizontal pump and two vertical branches. The piston

was surrounded by water, which rose and fell alternately in two columns: when it rose, compressing the air, and forcing it through the outlet valve; and when it fell, creating a vacuum, which was filled by air at atmospheric pressure.

The tunnel, on the 30th June, 1863, had been driven (including the advanced gallery) at Modane 1092·25 metres, and at Bardonnèche 1450·00 metres. The advancement in June last, at Modane, was at the rate of 4·719 feet per day. At this rate of progress at both ends, the tunnel would be finished in 9 years 2½ months from that time. It was not, however, too much to expect a progress of two metres per day at each end, seeing that machines had only been in use at Bardonnèche about two years and a half, and at Modane half a year. A great part of that time had been taken up in experiments, and the men were not thoroughly habituated, as yet, to the manipulation of the machines. The machines were also being much improved. With an average rate of 2 metres per day, from June 30th, 1863, 6 years and 7 months would be required for the completion of the tunnel, as compared with 26 years 3 months by hand-labor, at 1·655 feet per day at each end, the average rate of progress previous to the introduction of the machinery. The machinery in use at Mont Cenis was made for the greater part at Seraing, near Liège. M. Sommeiller confidently expected, an advancement of three metres per day at each end. If that were the average from June 30th, 1863, the work would be completed in 4 years 8½ months from that time.

In the advanced gallery at Modane, the number of workmen employed during the twenty-four hours was a follows:—

88 machinists, in two sets of 44 each.
9 chargers in one set.
30 laborers for removing the déblais, in one set.

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344 men were also engaged in enlarging and walling, giving a total employed underground of—

471, and including blacksmiths, stone-dressers, and other laborers at the surface, there were employed at the tunnel, . . .	700
Mechanics, brakesmen, &c., in the workshops, machinery, &c. .	240
Occasional laborers, ...	200
Or a total at Modane of	1140

At Bardonnèche the number was greater; 1200 to 1400 being generally employed, giving a total of 2540 on the works.

The result of a rough comparison was to show that in the present development of the Sommeiller system, an advancement three times quicker than by hand-labor might be effected, but at about two and a half times the cost; judging rather of places where it might be generally applied than by Mont Cenis only. The proportion of two and a half to one increase of cost, referred only to what was known as mining charges in the advanced gallery, *i. e.*, wages, tools, candles, and gunpowder. This proportion was notably diminished in the case of a railway tunnel, where enlarging, timbering, walling, laying of rails, &c., were charges common to both systems. In the case of a tunnel,

through rock, costing when completed £30 per yard, the two systems might compare as follows :—an increased advancement in favor of machinery of 3 to 1, at an increased cost of 4 to 3.

The ventilation was good in the advanced gallery, the exhaust air from the machines afforded an ample supply. During the time of exploding the holes, a jet of air was left open. Further back, where the men were employed in enlarging the tunnel, the ventilation was insufficient. The tunnel was therefore being divided with a horizontal brattice,—the upper section being in communication with the chimney on the mountain side. The air was intended to pass along the under-side of this division, and then return by the upper part, which had an area of 7 square metres.

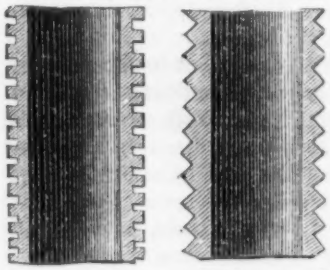
The works were now performed at the charge of the Italian Government. On their completion the French Government was to pay £760,000 for that portion of the tunnel situated in its territory—one-half the entire length—together with a premium of £20,000 for each year by which a term of 25 years counting from January 1st, 1862 was reduced. This premium would be increased to £24,000 for each year by which a term of 15 years was reduced, counting from the same time. In addition, the French Government would pay interest at five per cent. per annum on such portion of the tunnel as was finished. If, however, the Italian Government did not complete the work within twenty-five years from the time of making the agreement, or if they renounced the works before that time, the French Government was absolved from further payment. If the works were finished, as there was every reason to suppose they would be, in ten years from June 30th, 1863, the French Government would pay £1,287,000 for the construction of one-half of the tunnel, or at the rate of £210 per metre.

Proc. Inst. Civil Eng., Feb. 16, 1864.

Locomotive Improvement.

From the London Mechanics' Magazine, Sept., 1863.

SIR :—Much has already been done to increase the heating surface of steam boilers, but I think a further improvement may be effected by increasing the *surface in contact with the water*, without a further increase of the absorbent surface.



It is pretty generally known that flanges cast on air warming apparatus, as applied by the London Warming and Ventilating Company, greatly increase the effect of such apparatus, the cause being that a greater surface of heated metal is in contact with the air. I think, therefore, that if the metallic surface of tubes, flues, &c., of boilers, in contact with the water, be increased in area, an increase of evaporation will ensue. This may be effected in several ways, varying with the form of boiler ; but, in the case of locomotive boilers, the two modes

shown in the accompanying sectional diagrams, might be found most simple and effective.

Neither the thickness or the weight of the tubes need be much, if at all, increased. T. Moy.

Clifford's-Inn, Sept., 5, 1863

Experiments to determine the effects of Impact Vibratory Action, and a Long-continued change of load on Wrought Iron Girders. By William Fairbairn, LL.D., F.R.S.

From the London Artizan, April, 1864.

The following is an abstract of Mr. Fairbairn's communication. The author observed that the experiments which were undertaken, nearly twenty years ago, to determine the strength and form of the Tubular Bridges which now span the Conway and Menai Straits, led to the adoption of certain forms of girder, such as the tubular, the plate, and the lattice-girder, and other forms founded on the principle developed in the construction of these bridges. It was at first designed that the ultimate strength of these structures should be six times the heaviest load that could ever be laid upon them, after deducting half the weight of the tubes. This was considered a fair margin of strength; but subsequent considerations, such as generally attend a new principle of construction with an untried material, showed the expediency of increasing it; and instead of the ultimate strength being six times, it was in some instances increased to eight times the weight of the greatest load.

The proved stability of these bridges gave increased confidence to the engineer and the public, and for several years the resistance of six times the heaviest load was considered an amply sufficient provision of strength.

But a general demand soon arose for wrought iron bridges, and many were made without due regard to first principles, or to the law of proportion necessary to be observed in the sectional areas of the top and bottom flanges, so clearly and satisfactorily shown in the early experiments. The result of this was the construction of weak bridges, many of them so ill-proportioned in the distribution of the material as to be almost at the point of rupture with little more than double the permanent load. The evil was enhanced by the erroneous system of contractors tendering by weight, which led to the introduction of bad iron, and in many cases equally bad workmanship.

The deficiencies and break-downs which in this way followed the first successful application of wrought iron to the building of bridges, led to doubts and fears as to their security. Ultimately it was decided by the Board of Trade that in wrought iron bridges the strain with the heaviest load should not exceed 5 tons per square inch; but on what principle this standard was established does not appear.

The requirement of 5 tons per square inch did not appear sufficiently definite to secure in all cases the best form of construction. It is well-known that the power of resistance to strain in wrought iron are

widely different, according as we apply a force of tension or compression; it is even possible so to disproportion the top and bottom areas of a wrought iron girder calculated to support six times the rolling load, as to cause it to yield with little more than half the ultimate strain or 10 tons on the square inch. For example, in wrought iron girders with solid tops, it requires the sectional area in the top to be nearly double that of the bottom to equalize the two forces of tension and compression; and unless these proportions are strictly adhered to in the construction, the 5-ton strain per square inch is a fallacy which may lead to dangerous errors. Again, it was ascertained from direct experiment that double the quantity of material in the top of a wrought iron girder was not the most effective form for resisting compression. On the contrary, it was found that little more than half the sectional area of the top, when converted into rectangular cells, was equivalent in its powers of resistance to double the area when formed of a solid top plate. This discovery was of great value in the construction of tubes and girders of wide span, as the weight of the structure itself (which increases as the cubes, and the strength only as the squares) forms an important part of the load to which it is subjected. On this question it is evident that the requirements of a strain not exceeding 5 tons per square inch cannot be applied in both cases, and the rule is therefore ambiguous as regards its application to different forms of structure. In that rule, moreover, there is nothing said about the dead weight of the bridge; and we are not informed whether the breaking weight is to be so many times the applied weight plus the multiple of the load, or, in other words, whether it includes or is exclusive of the weight of the bridge itself.

These data are wanting in the railway instructions; and until some fixed principle of construction is determined upon, accompanied by a standard measure of strength, it is in vain to look for any satisfactory results in the erection of road and railway bridges composed entirely of wrought iron.

The author was led to inquire into this subject with more than ordinary care, not only on account of the imperfect state of our knowledge, but from the want of definite instructions. In the following experimental researches he has endeavored to ascertain the extent to which a bridge or girder of wrought iron may be strained without injury to its ultimate powers of resistance, or the exact amount of load to which a bridge may be subjected without endangering its safety—in other words, to determine the fractional strain of its estimated powers of resistance.

To arrive at correct results and to imitate as nearly as possible the strain to which bridges are subjected by the passage of heavy trains, the apparatus specially prepared for the experiments was designed to lower the load quickly upon the beam in the first instance, and next to produce a considerable amount of vibration, as the large lever with its load and shackle was left suspended upon it, and the apparatus was sufficiently elastic for that purpose.

The girder subjected to vibration in these experiments was a wrought iron plate beam of 20 ft. clear span, and the following dimensions:—

Area of top,	4·30 square inches.
Area of bottom,	2·40 "
Area of vertical web,	1·90 "
Total sectional area,	8·60 "
Depth,	16 inches.
Weight,	7 cwt. 3 qrs.
Breaking-weight (calculated),	12 tons.

The beam having been loaded with 6643 lbs., equivalent to one-fourth of the ultimate breaking-weight, the experiments commenced as follows:—

EXPERIMENT I.—*Experiment on a wrought iron beam with a changing load equivalent to one-fourth of the breaking-weight.*

Date.	Number of changes of Load.	Deflection produced by Load.	Remarks.
1860.			
March 21,	0	0·17	Strap loose on the 24th March.
April 7,	202,890	0·17	Strap broken on the 20th April.
May 1,	449,280	0·16	
May 14,	596,790	0·16	

The beam having undergone about half a million changes of load by working continuously for two months night and day, at the rate of about eight changes per minute, without producing any visible alteration, the load was increased from one-fourth to two-sevenths of the statical breaking-weight, and the experiments were proceeded with till the number of changes of load reached a million.

EXPERIMENT II.—*Experiment on the same beam with a load equivalent to two-sevenths of the breaking-weight, or nearly 3½ tons.*

Date.	Number of changes of Load.	Deflection in inches.	Remarks.
1860.			
May 14,	0	0·22	In this experiment the number of changes of load is counted from 0, although the beam had already undergone 596,790 changes, as shown in the preceding Table.
May 22,	85,820	0·22	
June 9,	236,460	0.21	
June 26,	403,210	0·23	The beam had now suffered one million changes of load.

After the beam had thus sustained one million changes of load without apparent alteration, the load was increased to 10,486 lbs., or $\frac{3}{5}$ths of the breaking-weight, and the machinery again put in motion. With this additional weight the deflections were increased, with a permanent

set of ·05 in., from ·23 to ·35 in., and after sustaining 5175 changes, the beam broke by tension at a short distance from the middle. It is satisfactory here to observe that during the whole of the 1,005,175 changes none of the rivets were loosened or broken.

The beam broken in the preceding experiment was repaired by replacing the broken angle-irons on each side, and putting a patch over the broken plate equal in area to the plate itself. A weight of 3 tons was placed on the beam thus repaired, equivalent to one-fourth of the breaking-weight, and the experiments were continued as before.

EXPERIMENT III.

Date.	Number of changes of Load.	Deflection in inches.	Permanent set in inches.	Remarks.
1860.				
August 9,	158	. .	. .	The load during these changes was equivalent to 10,500 lbs., or 4·6875 tons at the centre. With this weight the beam took a large but unmeasured set.
August 11,	12,950			During these changes the load in the beam was 8025 lbs., or 3·58 tons.
August 13,	24,900	0·22	?	
August 13,	25,900	0·18	0	
December 1,	768,100	0·18	0·01	Load reduced to 2·96 tons, or ¼th the breaking-weight.
1861.				
March 2,	1,602,000	0·18	0·01	
May 4,	2,110,000	0·17	0·01	
September 4,	2,727,754	0·17	0·01	
October 16,	3,150,000	0·17	0·01	

At this point, the beam having sustained upwards of 3,000,000 changes of load without any increase of the permanent set, it was assumed that it might have continued to bear alternate changes to any extent with the same tenacity of resistance as exhibited in the foregoing Table. It was then determined to increase the load from one-fourth to one-third of the breaking-weight; and accordingly 4 tons were laid on, which increased the deflection to ·20

EXPERIMENT IV.

Date.	Number of changes of Load.	Deflection in inches.	Permanent set in inches.	Remarks.
1861.				
October 18,	0	0·20	0	
November 18,	126,000	0·20		
December 18,	237,000	0·20		
1862.				
January 9,	313,000	. .	. .	Broke by tension across the bottom web.

Collecting the foregoing series of experiments, we obtain the following summary of results:—

SUMMARY OF RESULTS.

No. of Expt.	Date.	Weight on middle of the beam in tons.	Number of changes of Load.	Strain per square inch on bottom.	Strain per square inch on top.	Deflection, in inches.	Remarks.
1	From March 21 to May 14, 1860,	2·	596,790	4·62	2·58	·17	
2	From May 14 to June 26, 1860,	3·50	403,210	5·46	3·05	·23	
3	From July 25 to July 28, 1860,	4·68	5,175	7·31	4·08	·35	Broke by tension a short distance from the centre of the beam.

BEAM REPAIRED.

4	Aug. 9, 1860,	4·68	158	7·31	4·08	. .	The apparatus was accidentally set in motion.
5	Aug. 11 & 12,	3·58	25,742	3·59	3·12	·22	
6	From Aug. 13, 1860, to Oct 16, 1861,	2·96	3,124,100	4·62	2·58	·18	
7	From Oct. 18, 1861, to Jan. 9, 1862,	4·00	313,000	6·25	3·48	·20	Broke by tension as before, close to the plate riveted over the previous fracture.

From these experiments it is evident that wrought iron girders of ordinary construction are not safe when submitted to violent disturbances equivalent to one-third the weight that would break them. They, however, exhibit wonderful tenacity when subjected to the same treatment with one-fourth the load; and assuming therefore that an iron girder bridge will bear with this load 12,000,000 changes without injury, it is clear that it would require 328 years at the rate of 100 changes per day before its security was affected. It would, however, be dangerous to risk a load of one-third the breaking-weight upon bridges of this description, as, according to the last experiment, the beam broke with 313,000 changes; or a period of eight years, at the same rate as before, would be sufficient to break it. It is more than probable that the beam had been injured by the previous 3,000,000 changes to which it had been subjected; and assuming this to be true, it would follow that the beam was undergoing a gradual deterioration which must sometime, however remote, have terminated in fracture.

A Bridge over the Straits of Messina.

From the Lond. Practical Mechanic's Journal, May, 1864.

According to the Italian journals, it is in contemplation to unite Sicily to the main land by a bridge. The bridge proposed would be a suspension one, on a new system, the chains being of cast steel, and strong enough to support the weight of several railway trains.

MECHANICS, PHYSICS, AND CHEMISTRY.

Compressed Asphalte.

From the Lond. Mechanics' Magazine, April, 1864.

At a recent meeting, M. Malo read a very interesting paper, "On Compressed Asphalte as a material for roads," before the Society of Civil Engineers, at Paris. After referring to the defects inherent in all the old systems of paving adopted in the French capital, M. Malo treated of the attempts which had from time to time been made to substitute something better. Of all the systems tried, however, he stated that but one had borne the requisite tests, and that after a trying novitiate, extending over a period of ten years, compressed asphalte now took a place as a powerful rival to ordinary stone paving and Macadam.

The asphalte employed for the works already executed in Paris is a pure carbonate of lime, naturally impregnated with from six to ten per cent. of bitumen. The rock is quarried in regular beds, four to seven yards thick, at Seyssel (Ain), Val de Travers (canton de Neufchatel), and in several other places in the Jura. At a temperature equivalent to that of boiling water, the bitumen softens so much that the stone crumbles to powder; if now this powder, while still hot, be powerfully compressed, it will form masses possessing, when cold, an amount of hardness equal to that of the unquarried rock, and it is this peculiar property which has been somewhat recently applied on an extended scale, to the formation of roadways in Paris.

M. Malo stated that the crude asphalte is first broken by mechanical means into small pieces, then reduced to powder, and subsequently placed in large iron cauldrons, wherein it is heated to about 140 degrees Cent. While thus hot it is carried quickly in suitable ladles, to the locality where it is to be employed. The proper curved form which the finished road is intended to assume has been previously imparted to a bed of concrete (*Beton*), on which the hot asphalte, in powder, be it observed—for the pressure is needed to make it agglomerate—is spread, and carefully rammed, with heated cast iron rammers, into a solid sheet, so to speak. Three heavy rollers are then passed successively over the gradually hardening roadway. The first weighs about 5 cwt., the second 1 ton, and the third roller about 2 tons 5 cwt. By this means the stratum of asphalte is reduced to a uniform thickness, fixed in Paris at four centimetres. Two or three hours after the passage of the last roller the material has become so far cooled and consolidated that traffic can be freely resumed on its surface.

In 1850, one year after the discovery of this process, M. Darcy, inspector general of roads, proposed its application to a portion of the boulevards; but it was not until 1854 that the first piece of compressed asphalte pavement was put down, in the Rue Bergère, under the superintendence of MM. Homberg, chief engineer, and Vaudry, engineer in ordinary in the municipal service. In 1854 we find that about 700 or 800 metres only of the new roadway were in existence. In 1858 the area had increased, to 8000 metres, and now it is more than 100,-

000 metres, without including many large court-yards, for which the new pavement has been selected, less for the sake of solidity than for the absence of noise which follows on its use. As in all other new things, M. Malo stated, that many mistakes were made at first, many mishaps met with, and difficulties overcome. We will mention a few of the more important.

The first essential was obviously to discover a good method of preparing the material. After months of labor and care this object seemed as far from being obtained as ever. Then followed the difficulties of application, and in this department the experiments conducted in the Rue Neuve Petits Champs were fertile in instruction. The asphalte used was hard and unmanageable; the season far advanced, and it was a matter of some difficulty to procure a dry surface of concrete for the asphalte to rest on. The moisture was evaporated by the heat, and, pervading the mass, prevented the efficient agglomeration of its particles. Worst of all, the concrete itself reposed on soil recently disturbed in the formation of a sewer, and the settlement which followed, as a matter of course, led to the rupture of the bed of asphalte. Ultimately all these obstacles were overcome, and M. Malo states the advantages of the new roadway as follows:—It produces neither mud nor dust; the annual wear equalling only one millimetre, once it has become thoroughly consolidated by the passage of vehicles. It is almost perfectly noiseless—no trifling advantage, be it remarked. What would not we dwellers in London give for a noiseless pavement? The labor of horses is materially lessened on the compressed asphalte, as compared with stone paving or Macadam; a fact disputed, however, by M. Tresca, a gentleman who has conducted a valuable series of experiments on the tractive resistances of various roads. The expense of maintaining wheel carriages in repair is considerably reduced by the suppression of ruts and jolting. M. Malo stated the saving at 8,500,000 francs, supposing all Paris asphalted, yearly; and, lastly, the absence of vibration tends to the durability of the houses on either side. In opposition, it has been urged that the new pavement is too slippery for smoothly shod carriage and saddle horses (*chevaux de Luxe*). According to M. Malo, this inconvenience is never experienced unless the curvature of the roadway is exaggerated, or on steep hills. This has been verified by experience. It was found that one horse in 1308 fell in passing through the Rue de Sèze, which is paved, and but one in 1409 in passing through the Rue Neuve des Capucin, which is asphalted. Sometimes, however, the surface is rendered slippery by the presence of foreign substances dropped in traffic. A simple washing removes the evil. The same end may be attained by means of a slight sprinkling of sand.

M. Malo estimated the cost of the different roadways used in Paris, at the following rates per square metre:—

Material.	Formation.	Annual Maintenance.
Compressed Asphalte and Concrete,	15 f.	1 f. 25 c.
Pavement of Belgian Porphyry,	10 f. to 22 f.	0 f. 50 c. to 1 f. 50 c.
Macadam,	7 f.	2 f. 40 c. to 3 f.

M. Malo concluded by stating that all the Jura district, from the department of the Bas Rhine to Savoy, abounds in asphalte, so that no fears need be entertained of exhausting the supply by extending the application of the material.

Cement for Steam Joints, &c.

From the London Builder, No. 1073.

Plumbago has recently been introduced as the basis of a cement for steam-joints, and the general metallic connexions of the engineer. It is composed of six parts of plumbago, three of slacked lime, eight of sulphate of baryta, and three of boiled linseed oil. This compound, it is said, secures a perfectly air and steam-tight joint, much superior to that obtained by the use of red lead.

Resistances to Bodies passing through Water. By Mr. G. H. Phipps.

[Read before the Insti. of Civil Eng., March 8 and 15, 1864.]

From the London Mechanics' Magazine, March, 1864.

These resistances comprised the plus resistance, or that concerned in moving out of the way the fluid in advance of the body; the minus resistance, or the diminution of the statical pressure behind any body when put into a state of motion in a fluid; and the frictional resistance of the surface of the body in contact with the water.

The plus resistance of a plane surface one foot area, moving at right angles to itself in sea water, was considered to be

$R = \frac{64{\cdot}2 \times v_2}{2g}$, and the minus resistance was one-half the plus resistance.

For planes moving in directions not at right angles to themselves, theoretical resistances were, for the plus pressure—

$$s = \frac{a}{r^2}, \text{ and } R = \frac{s\,64{\cdot}2\,v^2}{2g}$$

the minus pressure being one-half the above; where R was the resistance of the inclined plane; a, the area of the projection of the inclined plane upon a plane at right angles to the direction of motion; r, the ratio of the areas of the projected and the inclined planes; and s, the area of a square-acting plane of equivalent resistance with the inclined plane.

But, besides these theoretical resistances, the experiments of Beaufoy showed, that when the inclined planes were of moderate length only, the plus resistance was considerably in excess of the above; so that when the slant lengths of the planes were to their bases in the proportion of 2 to 1, 3 to 1, 4 to 1, and 6 to 1,

the actual resistances exceeded the theoretical, as

1·1 to 1, 1·98 to 1, 3·24 to 1, and 6·95 to 1.

The author proposed a method of approximating to these additional resistances, by adding the constant fraction $\frac{1}{7}$th of a square foot for every foot in depth of the plane, to the quantity s previously deter-

mined, which empirical method he found to agree nearly with the results of Beaufoy's experiments.

The resistances of curved surfaces, such as the bows of ships, were adverted to, the method of treating them being to divide the depth of immersion into several horizontal layers, and then again into a number of straight portions, and to deal with each portion as a separate detached plane, according to the preceding rules.

The question of friction was then considered. The experiments of Beaufoy were referred to, giving 0·339 lbs. per square foot as the co-efficient of friction for a planed and painted surface of fir, moved through the water at 10 feet per second, the law of increase being nearly as the squares of the velocities, viz: the 1·949 power. The author was, however, of opinion that a surer practical guide for determining the co-efficient of friction would be, by considering all the data and circumstances of a steamship of modern construction, moving through the water at any given speed. The actual indicated horse-power of the engines being given, the slip of the paddles being known, and the friction and other losses of power approximated to, it was clear that the portion of the power necessary to overcome the resistance of the vessel might be easily deduced. By determining approximately, by the preceding rules, the amounts of the plus, the minus, and the additional head resistances, and deducting them from the total resistance, the remainder would be the resistance due to the friction of the surface. By this process, and taking as an example, the iron steamship "Leinster," when perfectly clean, and going on her trial trip 30 feet per second in sea water, her immersed surface being 13,000 sq. ft. the co-efficient of friction came out at 4·34 lbs. per sq. ft.* Beaufoy's co-efficient of 0·339 lb. per square foot at 10 feet per second, would, according to the square of the velocities amount to 3·051 lbs. at 30 ft. per second. The difference between this amount and the above 4·34 lbs. might be accounted for by a difference in the degree of roughness of the surfaces.

Other methods for the determination of the co-efficient of friction were then discussed. One, derived from the known friction of water running along pipes, or water courses, was shown to be considerably in excess of the truth. It was founded upon the observed fact, that, at a velocity of 15 feet per second, the friction of fresh water on the interior of a pipe was 25 ozs.† per square foot. Applying this to the ship "Leinster," and increasing the friction as the squares of the velocities up to 30 feet per second, the above friction would become 100 ozs., or 6¼ lbs. per square foot, which acting upon, 13,000 square feet of surface, would absorb, at the above speed no less than 4396 H.P., whilst the total available power of the engines, (after deducting from the indicated 4751 H.P. $\frac{1}{10}$th for friction, working air-pumps, and

* Since the paper was written, the accuracy of the above co-efficient had been confirmed very nearly, by an examination of another vessel, the "Atrata" of different type from the "Leinster" the calculations of which were given in an Appendix.

† For sea-water this quantity must be increased as the specific gravity, or as 62·5 to 64·2.

other losses, and $\frac{1}{5}$th of the remainder for the observed slip,) was only 3421 H.P.; that showing an excess of resistance equal to 974, H.P., without allowing any power to overcome the other resistances. The assumption of 25 ozs. being the proper measure of the friction per sq. ft. at a velocity of 15 ft. per second, upon the clean surface of an iron ship, seemed to have arisen from the opinion, very gererally entertained, that there was no difference in the amount of friction in pipes and water-courses, whether internally smooth like glass, or moderately rough like cast iron, and that the surfaces of ships were subject to the same action. The comparatively recent experiments, in France, of the late M. Henry Darcy, were in opposition to the above view, and showed that the condition as to roughness of the interior of a pipe modified the friction considerably. Thus, with three different conditions of surface, the co-efficients were:—

A. Iron plate covered with bitumen made very smooth,	0·000432
B. New cast iron,	0·000584
C. Cast iron covered with deposits,	0·001167

The friction was, therefore, nearly as 1, $1\frac{1}{2}$ and 3.

As there appeared no reason to doubt the correctness of M. Darcy's experiments, even in pipes the notion of the friction being uninfluenced by the state of roughness of the interior could no longer be entertained. The 25 ounces, previously mentioned as the measure of friction per square foot for the interior of pipes and water-courses, could not, therefore, be regarded as a constant quantity, applicable to all kinds of surfaces; but from the author's calculations, it appeared to come in intermediately between the co-efficients of the surfaces B and C, given in the above scale; as at 15 feet per second.

A would give	$13\frac{1}{2}$	ounces	per	square foot.
B	" 20	"	"	
C	" 40	"	"	

Besides, there was another cause for an excess of friction in pipes and water-courses, over that upon ships, even when the surfaces were equally smooth. It arose from the circumstance, that where the velocity of the water in a pipe, or open water-course, was spoken of, the meaning was, its average velocity; whilst the velocity of a vessel through still water meant what the words implied, namely, the relation of the vessel's motion to the fluid at rest. If the case were taken of a water-course of such width, that the friction of the bottom only need be considered, with an average velocity of flow of 15 feet per second, the friction upon the bottom would be equal to 25 ozs. per square foot.; but according to the rules generally used, an average velocity of 15 ft. per second corresponded to a surface velocity of 16·66 feet per second which was the velocity with which a vessel should pass through still water, to give an equal friction upon its sides. According to Beaufoy, the velocity of 16·66 feet per second would produce a friction of ·932 lbs. or 14·91 ozs., where 15 feet would only give 12·2 ozs. The difference between the 14·91 ozs. and 25 ozs. (equal to 10·09 ozs.) must therefore, be set down to the different degree of roughness of the surfaces in the water-course and the vessel.

Taking, then, 4·34 lbs. as the friction per square foot of a new iron

ship, moving through the water at a speed of 30 feet per second, it would be found that this was equal to the 1-207·06th part of the plus resistance of a plane 1 foot square, moving through the water at right angles to itself at the above velocity. Also, as the resistance of both planes increased according to the same law of the square of the velocities, the ratio of 1 to 207·06 would subsist at all velocities.

$$\text{The ratio was as } \frac{64{\cdot}2\,v^2}{2g} \text{ to } 4{\cdot}34 \text{ lbs.} = \frac{1}{207{\cdot}06}$$

Calling the ratio r, and the whole fractional surface in square feet s, and S, as before, the area of a square-acting plane of equivalent resistance, then $S = s \div r = s \div 207{\cdot}06$.

As an example of the application of the previous deductions, the performance of the steamship "Leinster," on her trial trip, when going through sea-water at a speed of 30 feet per second was referred to. In this case—

m, the area of the immersed midship section was	336 sq. ft.
d, the draft of water,	13 ft.
r, the reduced ratio of the slant length of the bow to the projection,	10 to 1.
r', the same for the stern,	10 to 1.
r', the ratio of one square foot of square-acting plane, to 1 square foot of frictional surface,	207·06 to 1.
v, the velocity in feet per second,	30
w, the weight of a cubic foot of sea water,	64·2 lbs.
f, the area of the frictional surface,	13,000 sq. ft.

Calling P, the plus, or head resistance; M, the minus, or stern resistance; A, the additional head resistance; F, the fractional, or surface resistance; S, the area of a square-acting plane having an equal resistance with each of the above; and R, the total resistance;

$$\text{Then, } P = \frac{m}{r^2} = S = \frac{336}{100} = 3{\cdot}36 \text{ sq. ft.}$$

$$\text{“ } M = \tfrac{1}{2}\frac{m}{r^2} = S = \tfrac{1}{2}\frac{336}{100} = 1{\cdot}68 \text{ “}$$

$$\text{“ } A = \frac{13}{7} = S = 1{\cdot}86 \text{ “}$$

$$\text{“ } F = \frac{13000}{207{\cdot}06} = S = 62{\cdot}78 \text{ “}$$

$$S = \overline{69{\cdot}68} \text{ “}$$

$$R = 69{\cdot}68 \times \frac{64{\cdot}2\,v^2}{2g} = 69{\cdot}68 \times 900 = 62{,}712 \text{ lbs.}$$

H (Realized power) $= 62{,}712 \text{ lbs.} \times 30 \div 550 = 3420{\cdot}66$ H.P.

H′ (Gross power) including the slip and other losses, $= 3420{\cdot}66 \times \frac{100}{72}$ $= 4751$ H.P.

Thus, by ascertaining the value of S for any vessel, which was entirely independent of velocity, it would be easy to determine the power

necessary to propel it at any required speed, or the speed being given, to find the corresponding power.

Generally $\text{H} = \text{V}^3 \text{S} \frac{64{\cdot}2}{2g} \div 550.$ . . (1)

Or, because for sea-water 64·2 was very nearly equal to $2g$,

$$\text{H} = \frac{\text{V}^3 \text{S}}{550} \quad . \quad . \quad . \quad (2)$$

When the slip and other losses were in the same proportion as in the "Leinster." $*\text{H}' = \text{H} \frac{100}{72}$ . . (3)

When the gross power was given, and the velocity was required:—

$$\dagger \text{V} = \left\{ \frac{\frac{72}{100} \text{H}' \times 550}{\text{S} \frac{64{\cdot}2}{2g}} \right\}^{\frac{1}{3}} \quad . \quad (4)$$

The author then proceeded to examine the question of the influence of form in reducing the resistance of vessels.

It was argued that, in vessels of similar type to the "Leinster," where $\frac{9}{10}$ths of the whole resistance was due to friction, and only $\frac{1}{10}$th to considerations involving the question of "form," no minor modifications of the latter could have much effect in diminishing the total resistance. The case of other vessels of different type, more bluff in the bows and not so fine in the run, was adverted to, and a particular instance was discussed, where the inertial resistance was supposed to be equal to one-fifth of the total resistance, and the slant length of the bows to the base to be as 6 to 1. If such a vessel were altered, so as to make the above proportion $8\frac{1}{2}$ to 1, the improvement would only diminish the total resistance by $\frac{1}{10}$th.

In opposition, however, to this view, the author referred to several ships, the particulars of which were given in the discussion upon Mr. Armstrong's Paper on "High Speed Steam Navigation," (Minutes of Proceedings, Inst. C. E. vol. xvi.) These vessels were the "Rifleman," the "Teazer," the "Dwarf," the "Magnet," the "Flying Fish," and two vessels by Mr. Scott Russell. By moderate improvements in the bows and run of the above vessels, the resistance was diminished to degrees varying from $\frac{1}{2}$ to $\frac{1}{9}$th of the whole, a considerably greater improvement than could be accounted for upon the principles of calculation in the Paper.

Without attempting to solve the difficulty, the author threw out, as a suggestion for examination, whether, as nearly all the above vessels were propelled by screws, the improvements noted might not be referable to an improved action in the propelling instrument, brought about by an alteration in the hulls of the vessels, and the question suggested itself whether, if the resistances of the vessels in question could have been ascertained by means of dynamometer applied to a towing-rope, the improvement would have been so great, as when shown by the diminished power of the engines.

* If for fresh water $\text{H}' \times 0{\cdot}97 =$ gross H.P. † If for fresh water $\text{V} = 0{\cdot}99 =$ velocity.

For the Journal of the Franklin Institute.

Economy in the Use of Steam. By D. M. Greene, C. E. Second Assist. Eng. U.S.N.

The special attention which has been recently attracted to this important subject, and the interest in it, which has been developed in popular no less than in professional minds, together with the wholly unsatisfactory and unprofitable popular discussions in relation to it, have induced the writer to undertake a reconciliation of the results of *experiment* with those of *theory*.

The experimental results alluded to, are the conclusions arrived at in the case of the experiments made some years since, at Erie, Pa., under the auspices of the United States Government, for the purpose of ascertaining the relative costs of net power, when steam is used with different measures of expansion; conclusions which are generally assumed to be entirely at variance with the theory hitherto almost universally accepted as true.

In the discussion which is to follow, the law of Mariotte is accepted as practically governing the case; except so far as it is necessarily modified by the comparatively recent discovery, that when heat is employed as a motive force, or "mode of motion," the work done is due to the transmutation of a definite amount of heat into work. According to the theory based upon the discovery alluded to, and which is now generally accepted by competent authorities everywhere, as correct, whenever an amount of work, equivalent to 772 pounds raised 1 foot, is accomplished through the agency of heat, an amount of heat sufficient to raise 1 pound of water 1° Fahr. is transmuted into that work; in other words, the mechanical equivalent of a unit of heat* is 772 pounds raised 1 foot high; or, it is equal to a force of 772 pounds exerted over a space of 1 linear foot.

Hence for each horse power developed by a steam engine, there are $\frac{33000}{772} = 42{\cdot}746$ units of heat transmuted into power; and as a necessary consequence, such transmutation must be attended by a certain, definite, *condensation* in the cylinder; whence we are forced to the conclusion, that the volume of steam which enters the cylinder during each stroke must be greater than the space displaced by the piston, by the volume condensed to produce the power developed.

As a simple example, showing the extent of condensation due to the production of power in a particular case, take a cylinder whose piston has an area of 3300 square inches, 10 feet stroke, and makes 25 single strokes per minute; using a steam pressure of two atmospheres, or 29·4 pounds above zero. Then the total power developed, will be $\frac{3300 \times 29{\cdot}4 \times 10 \times 25}{33000} = 735$ horses; and the heat transmuted into power, $735 \times 42{\cdot}746 = 31418$ units.

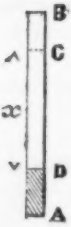
* By "unit of heat," is of course meant an amount of heat sufficient to raise 1 lb. of water 1° Fahr.

Now the total heat of steam of two atmospheres is 1190°; and its sensible temperature 250°: hence $\frac{31418}{1190-250} = 33{\cdot}4$ pounds, or $\frac{33{\cdot}4 \times 841}{62{\cdot}5} = 449$ cubic feet of steam will be condensed per minute. During the same time, the space displaced by the piston will be 5729 cubic feet, and the total volume of steam used, $5729 + 449 = 6178$ cubic feet; of which $\frac{449 \times 100}{6178} = 7{\cdot}26$ per cent. is condensed to produce the power.

In the preceding example, we have supposed the steam to follow full stroke; when high measures of expansion are employed, the condensation—being proportional to the work done—will, of course, be largely increased; as, for example, when steam is expanded four times, the condensation will be $2{\cdot}38\left(\frac{449 \times 100}{5729}\right) = 18{\cdot}66$ per cent. of the space displacement of the piston; so that, in order to realize the 2·38 units of work usually shown by theory to have been performed, the volume of steam admitted to the cylinder to do the work, and to preserve the tension must be $\frac{100 \times 100}{81{\cdot}34} = 1{\cdot}23$ units, instead of a single unit. It follows, therefore, that the gain in work, instead of being 138 per cent. of that realized when steam is used without expansion, is only $\frac{(238-123)\,100}{123}$ 93·5 per cent. We might easily modify this gain by the loss due to clearance, and by the constant prejudicial resistances of back pressure, and the friction of the engine itself; but we prefer to consider the general case, and deduce a formula which will give the *cost of a net horse-power, in pounds of water evaporated per hour*, under any and every variety of practical conditions, as regards pressure, expansion, clearance, back and friction pressures; enough however, has been said, to awaken a suspicion in the intelligent mind, that the extravagant gains promised by theory—as applied and heretofore generally relied upon—are but myths.

In order to best accomplish our purpose, it is necessary, in the first place, to calculate the

Mechanical Effect available from the Evaporation of 1 *pound of water per hour, the steam being used without Expansion.*



Let AB, Fig. 1, be a tube of indefinite length, having a sectional area equal to 1 square inch: suppose it to contain a column of water one foot high: upon this water let a piston rest without weight, and capable of motion without friction. Then, when this filament of water has been converted into steam, under the pressure of the atmosphere, the piston will have been raised through a height DC $= x$; and an amount of work $\quad W = 14{\cdot}7\,x$,

will have been done: in which x will represent the specific volume of steam of one atmosphere, less the condensation due to the production of the work + 1. To find the height of the tube due to the condensation, or the portion of the length of the tube which would have been occupied by the steam condensed, had no condensation occurred, we have $\frac{14{\cdot}7\,x}{772}$ = the number of pounds of water raised 1° by the heat transmuted into work; or putting T for the total heat, and t for the sensible temperature of the steam, $\frac{14{\cdot}7\,x}{772\,(\mathrm{T}-t)}$ = the number of pounds of water which would be converted into steam from, and at a temperature t, by, the same heat. If now, w represent the weight of a filament of water 1 foot high in the tube, we shall have, for the space occupied by the above weight of steam, in the state of water, $\frac{14{\cdot}7\,x}{772\,(\mathrm{T}-t)\,w}$ cubic feet. If V represent the specific volume of the steam, then will the above volume of water, as steam, occupy $\frac{14{\cdot}7\,\mathrm{V}\,x}{772\,(\mathrm{T}-t)\,w}$ feet of the length of the tube; whence

$$x = (\mathrm{V}-1) - \frac{14{\cdot}7\,\mathrm{V}\,x}{772\,(\mathrm{T}-t)\,w}.$$

or

$$x\left(1+\frac{14{\cdot}7\,\mathrm{V}}{773(\mathrm{T}-t)\,w}\right)=\mathrm{V}-1.$$

$$\therefore\quad x=\frac{\mathrm{V}-1}{1+\frac{14{\cdot}7\,\mathrm{V}}{772\,(\mathrm{T}-t)\,w}} \qquad (1)$$

To find V, let V_1 be the specific volume of steam, as compared with the original water at the temperature of 62° Fahr., and P represent the tension of the steam—above zero—in inches of mercury: then according to Fairbairn's empirical formula,

$$\mathrm{V}_1 = 25{\cdot}62 + \frac{49513}{\mathrm{P}+{\cdot}72}.$$

Making P = 30, we get $\mathrm{V}_1 = 1637$; but we are seeking the specific volume of the steam as compared with the original water at the boiling point—212° in this case: to determine this, we make use of the relation that the specific volumes of the steam are inversely proportional to the volumes of a given weight of water at the two temperatures mentioned, thus;

$$\mathrm{V} : \mathrm{V}_1 :: 1 : 1{\cdot}0365, \text{ *}$$

whence

$$\mathrm{V} = \frac{\mathrm{V}_1}{1{\cdot}0365} = \frac{1637}{1{\cdot}0365} = 1579.$$

* The volumes of a given weight of water, at 62° and 212°, are to each other as 1 : 10365,—very nearly.

Also at 212°, $w = \cdot 42$ of a pound; $T = 1178 \cdot ^\circ 6$; $t = 212^\circ$.
Substituting these values in (1) we get

$$x = \frac{1579 - 1}{1 + \frac{14 \cdot 7 \times 1579}{772(1178 \cdot 6 - 212) \cdot 42}}$$

$$= 1469 \cdot 3 \text{ feet.}$$

Hence the work done by $\cdot 42$ of a pound of water, when converted into steam of one atmosphere, $= 14 \cdot 7 \times 1469 \cdot 3 = 21598 \cdot 71$ lbs. ft.; consequently for the work done by a pound of water under the same circumstances, if evaporated in an hour and reduced to horse power, we have

$$\text{HP} = \frac{21598 \cdot 71}{33000 \times 60 \times \cdot 42,}$$

$$= \cdot 026. \qquad . \qquad . \qquad (2)$$

When steam is made under a pressure of 9 atmospheres, or $9 \times 14 \cdot 7 = 132 \cdot 3$ pounds per square inch, the work of a pound of water is found to be $\cdot 029$ of a horse-power; but in securing the gain thus indicated, an additional expenditure of heat is required; so that when the proper reduction is made, we get $\cdot 0281$ as the work accomplished by the same expenditure of heat or fuel that was required to develop the $\cdot 026$ of a horse-power of (2). Now, assuming that the increments of work between one and nine atmospheres are equal—which, though not strictly true, is sufficiently near the truth for practical purposes—we get the following values. w being the work of 1 lb. of steam per hour reduced to the standard of steam of one atmosphere.

Pressure in Atmospheres.	W.*	Remarks.
1	·026	Calculated.
2	·0261	Estimated.
3	·0263	"
4	·0266	"
5	·0269	"
6	·0272	"
7	·0275	"
8	·0279	"
9	·0281	Calculated.

In any case, to find the number of pounds of water required to be evaporated per horse-power (total), when the steam is used without

*The numbers in this column, although strictly correct for the work of equal quantities of fuel only, may also be taken as representing the work of a pound of water, in each case, without appreciable error. The object here aimed at is more particularly to afford a means of comparison of the work done by equal weights of fuel.

expansion, and in a cylinder without clearance, it is only necessary to take the reciprocal of w, thus:

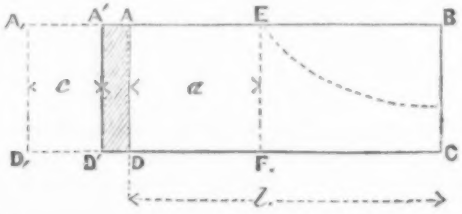
$$\text{cost} = \frac{1}{w}. \qquad . \qquad . \qquad . \qquad . \qquad (3)$$

If $w = \cdot 026$, $\text{cost} = \frac{1}{\cdot 026} = 38 \cdot 446$ pounds.

We next pass to an estimate of the

Effect of Clearance.

Fig. 2.



In Fig. 2, let

l = length of stroke = D C.

a = space traversed by the piston before the steam is cut off.

c = clearance = D′ D = altitude of a cylinder whose diameter equals that of the cylinder, and whose volume equals the clearance space.

1 = unity = initial pressure of the steam above zero.

p_1 = mean pressure when the work per stroke is calculated independently of the clearance.

p_2 = mean pressure when the clearance is considered.

Then,

1. Neglecting the clearance, and calling the work done before the steam is cut off, unity, the work done during expansion will be represented by *hyp. log.* $\frac{l}{a}$; and the whole work per stroke

$$1 + \textit{hyp. log.}\ \frac{l}{a}.$$

Dividing this result by the ratio of l to a, we get

$$p_1 = \frac{a}{l}\left[1 + \textit{hyp. log.}\ \frac{l}{a}\right]. \qquad . \qquad . \qquad (4)$$

2. Considering the clearance as a part of the stroke, and calling the work done before the steam is cut off, unity, as before—but a different unit—we have for the work done during expansion in terms of this last unit,

$$\textit{hyp. log.}\ \frac{l+c}{a+c}:$$

or, since the last unit is $\frac{a+c}{a}$ times as large as the first, this work, compared with the first, will be

$$\frac{a+c}{a}\ hyp.\ log.\ \frac{l+c}{a+c};$$

and, consequently, the work actually done by the steam during the entire stroke, in terms of the first unit, will be

$$1+\frac{a+c}{c}\ hyp.\ log.\ \frac{l+c}{a+c};$$

Dividing this by the ratio of l to a, as before, we get

$$p_2=\frac{a}{l}\left[1+\frac{a+c}{a},\ hyp.\ log.\ \frac{l+c}{a+c}\right]. \qquad (5)$$

It is clear that there has been a *loss in steam*, due to the clearance space, while, at the same time, there has been a *gain in work*, due to the expansion of the clearance steam; but the loss is greater than the gain—hence an absolute loss equal to their difference.

The loss in steam, compared with the cylinder steam, is $\frac{c}{a}$; while the gain in work, compared with the work done before cutting off, is $\frac{p_2-p_1}{p_1}$.

The steam and work, in the first case being respectively equal to unity, and in the second case to $1+\frac{c}{a}$, and $1+\frac{p_2-p_1}{p_1}$, respectively; and assuming that the work done under any given conditions, should be proportional to the steam used, we have for the absolute loss of steam—or work,

$$\left(1+\frac{c}{a}\right)-\left(1+\frac{p_2-p_1}{p_1}\right),$$

$$=\frac{c}{a}-\frac{p_2-p_1}{p_1};$$

and for the loss in terms of, or compared with, the steam used in the second case,

$$\frac{\frac{c}{a}-\frac{p_2-p_1}{p_1}}{1+\frac{c}{a}}.$$

$$\therefore\ \text{Loss}=\frac{c-\frac{a\,(p_2-p)}{p_1}}{a+c}. \qquad (6)$$

If now we substitute in (6), for p_2 and p_1, their values in (4) and (5), we obtain, first;

$$\frac{p_2 - p_1}{p_1} = \frac{\frac{a}{l}\left(1 + \frac{a+c}{a} \cdot hyp.\,log.\,\frac{l+c}{a+c}\right) - \frac{a}{l}\left(1 + hyp.\,log.\,\frac{l}{a}\right)}{\frac{a}{l}\left(1 + hyp.\,log.\,\frac{l}{a}\right)}$$

$$= \frac{\frac{a+c}{a}\,hyp.\,log.\,\frac{l+c}{a+c} - hyp.\,log.\,\frac{l}{a}}{1 + hyp.\,log.\,\frac{l}{a}};$$

which in (6) gives, for the clearance, an absolute

$$\text{Loss} = \frac{c - \frac{a\left[\frac{a+c}{a}\,hyp.\,log.\,\frac{l+c}{a+c} - hyp.\,log.\,\frac{l}{a}\right]}{1 + hyp.\,log.\,\frac{l}{a}}}{a+c}$$

$$= \frac{c}{a+c} - \frac{\left[hyp.\,log.\,\frac{l+c}{a+c} - \frac{a \,.\, hyp.log.\,\frac{l}{a}}{a+c}\right]}{1 + hyp.\,log.\,\frac{l}{a}}. \qquad (7)$$

By this formula, the following Table has been constructed; showing the losses due to clearance under the ordinary conditions of practice:

Cut-off.	Per cent. of Loss due to Clearance.			
	Clearance, 5 per cent.	Clearance 6 per cent.	Clearance 7 per cent.	Clearance 8 per cent.
$\frac{1}{10}$	20·90	23·65	26·48	28·93
$\frac{2}{10}$	13·60	16·68	18·73	20·90
$\frac{3}{10}$	11·25	13·19	15·03	16·18
$\frac{4}{10}$	9·40	11·01	12·60	14·18
$\frac{5}{10}$	8·09	9·57	10·98	12·21
$\frac{6}{10}$	7·20	8·47	9·76	10·97
$\frac{7}{10}$	6·47	7·59	8·79	9·84
$\frac{8}{10}$	5·79	6·84	7·85	8·98
$\frac{9}{10}$	5·21	6·23	7·19	8·16
$\frac{10}{10}$	4·76	5·66	6·54	7·69

Example.—Suppose it is found that, for a certain measure of expansion—without clearance—35 pounds of steam will be required per horse power per hour. Required the actual cost of a horse power when the clearance is 8 per cent. and the steam cut off at $\frac{2}{10}$.

We have

$$\text{Cost} = \frac{35 \times 100}{100 - 20 \cdot 90} = 44 \cdot 25 \text{ pounds:}$$

hence the absolute waste in this case will be $44 \cdot 25 - 35 = 9 \cdot 25$ pounds of steam per horse power, per hour.

This reduction in the efficiency of steam, it will be observed, is in addition to the reduction due to condensation: taken together they probably amount to 40 per cent. of all the steam used; the exact amount, however, is at present unimportant; the immediate design being simply to direct the reader's attention to the progress being made in clearing away the mists which have so long obscured this subject.

It will be observed that if 40 per cent. of the steam is lost, or rather if only 60 per cent. of it is utilized, we shall realize, from a unit of steam, only $2 \cdot 609 \times \cdot 6 = 1 \cdot 565$ units of work; that is, instead of realizing a gain of 1·609, we shall get only ·565; or about *one-third* the gain usually estimated for this measure of expansion.

We are now prepared to estimate the

Absolute Available Work, in a Unit of Steam or Water, for any measure of Expansion.

Let w_1 = the total work.

w = as before, the work due to a unit of steam, when used without expansion (2)

r = ratio of work theoretically due to a unit of steam, when used with any measure of expansion, to that done when the same steam is used without expansion—according to the theory as usually applied.

c_1 = loss due to clearance (7).

b = loss due to "blowing out."

Then retaining the previous notation we evidently have

$$w_1 = w r \left[(1 - c_1)(1 - b)\right]. \quad . \quad . \quad (8)$$

in which $$r = 1 + hyp.\ log.\ \frac{l}{a}$$

Substituting now this value, together with that of c_1 already found (7) in (8), we get

$$w_1 = w \left[1 - \left[\frac{c}{a+c} - \frac{\left(hyp.log.\ \frac{l+c}{a+c} - \frac{a\ hyp.log.\ \frac{l}{a}}{a+c} \right)}{1 + hyp.\ log.\ \frac{l}{a}} \right] \right] \left(1 + hyp.\ log.\ \frac{l}{a}\right)(1-b)$$

$$= w \left[\frac{a\left(1 + hyp.\ log.\ \frac{l}{a}\right)}{a+c} + hyp.\ log.\ \frac{l+c}{a+c} - \frac{a\ hyp.\ log.\ \frac{l}{a}}{a+c} \right] [1-b]$$

$$w \left[\frac{a}{a+c} + hyp.\ log.\ \frac{l+c}{a+c} \right] [1-b]. \quad . \quad (9)$$

The above expression would give the absolute work done by the steam, were it not for the fact that there is a loss of pressure between the boiler and the cylinder; that is, the initial cylinder pressure is always less than the boiler pressure; the difference being generally about three per cent. of the boiler pressure; although sometimes greater and sometimes slightly less. Hence if p be the boiler pressure above zero, in pounds, the initial cylinder pressure will be only $\cdot 97\,p$; while the average pressure during the stroke will be (4), without clearance,

$$\cdot 97\ p.\ \frac{a}{l}\left[1 + hyp.\ log.\ \frac{l}{2}\right]. \quad . \quad . \quad (9^a)$$

or the work actually done will be ·97 of that due to the steam made in the boilers and (9) becomes,

$$w_1 = \cdot 97\,w\left[\frac{a}{a+c} + hyp.\ log.\ \frac{l+c}{a+c}\right][1-b.] \quad . \quad (10)$$

The reciprocal of this, or $\frac{1}{w_1}$ will give the cost (c) of a horse-power per hour, in pounds of water evaporated, thus;

$$c = \frac{1}{\cdot 97 w\left[\frac{a}{a+c} + hyp.\ log.\ \frac{l+c}{a+c}\right][1-b]}. \quad . \quad (11)$$

But our object is to determine the net, or *effective* dynamic value of a unit of water—the surplus after deducting the constant prejudicial resistances of back-pressure, and the pressure due to the friction of the engine itself; which we will represent by v and f, respectively.

To correct the absolute dynamic value given by (9), it is only necessary to multiply that value by that fraction which expresses the value of the average effective pressure above zero, in terms of the boiler pressure: this value will obviously be (9^a)

$$\frac{\cdot 97\ p.\ \frac{a}{l}\left[1 + hyp.\ log.\ \frac{l}{a}\right] - [v+f]}{p}$$

which multiplied by (9) gives for the net effective dynamical value w_1' of a pound of water.

$$w_1' = \frac{w\left[\frac{a}{a+c} + hyp.\ log.\ \frac{l+c}{a+c}\right]\left[\cdot 97\ p.\ \frac{a}{l}\left(1 + hyp.\ log.\ \frac{l}{a}\right) - (v+f)\right][1-b]}{p.} \quad (12)$$

whence finally for the cost (c_1) of a net effective horse-power, we get

$$c_1 = \frac{1}{w_1'};$$

or

$$c = \frac{p}{w\left[\frac{a}{a+c} + hyp.\ log.\ \frac{l+c}{a+c}\right]\left[\cdot 97\ p.\ \frac{a}{l}\left(1 + hyp.\ log.\ \frac{l}{a}\right) - (v+f)\right][1-b]} \quad (13)$$

An inspection of (13)—observing the manner in which p enters in both numerator and denominator—shows us that the value of c will

be diminished by increasing p; by diminishing c, v, f, and b; and also that the slight increase of w, due to the increase of p, has the same tendency in a very slight degree.

We are now prepared to apply the formula to a practical

Example.—In the engines of the *Michigan*, under the conditions of the "Erie Experiments," $l = 96''$; $c = 5''57$; $v + f = 2{\cdot}7 + 2{\cdot}1 = 4{\cdot}8$; $p = 21 + 14{\cdot}7 = 35{\cdot}7$; and $\cdot 97\ p = 34{\cdot}63$. To determine the cost of a net horse-power in pounds of water, when the steam is cut off at $\frac{4}{10}$ of the stroke from the beginning.

Making, for simplicity, $l = 100$, c becomes 5·8, and $a = 40$; then, putting $b = 0$, for fresh water, (13) becomes

$$c = \frac{35{\cdot}7}{\cdot 026\left[\frac{40}{45{\cdot}8} + hyp.\,log.\frac{105{\cdot}8}{45{\cdot}8}\right]\left[34{\cdot}66 \times {\cdot}4\left(1 + hyp.\,log.\frac{100}{40}\right) - 4{\cdot}8\right]}$$

$$= \frac{35{\cdot}7}{\cdot 026\ (\cdot 873 + \cdot 837)[34{\cdot}66 \times {\cdot}4\ (1 + \cdot 916) - 4{\cdot}8]},$$

$$= \frac{35{\cdot}7}{\cdot 026 \times 1{\cdot}71 \times 21{\cdot}76} = \frac{35{\cdot}7}{\cdot 967} = 36{\cdot}92 \text{ pounds.} \quad . \quad (14)$$

In the "Erie Experiments," the cost, when cutting off at $\frac{4}{9}$, was found to be 36·235 lbs.

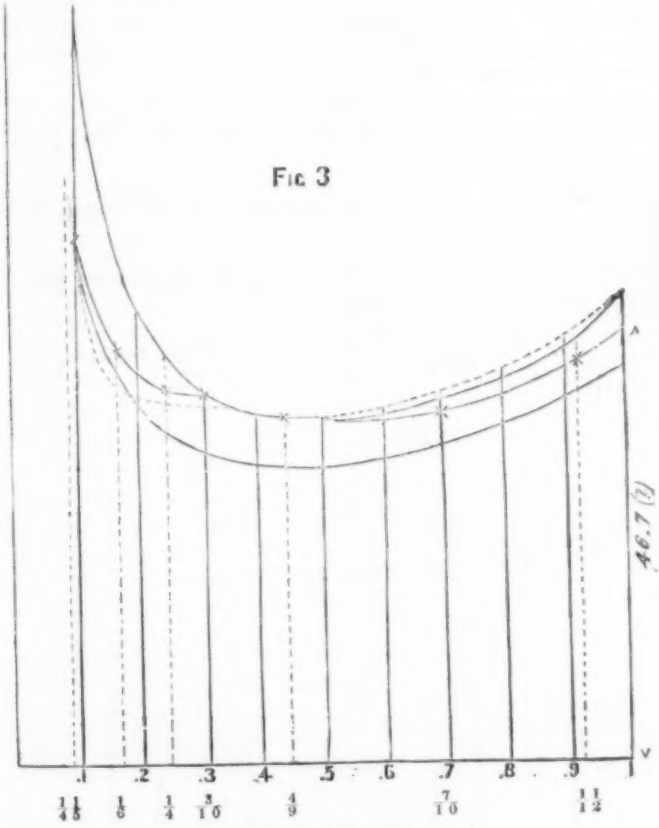
Thus, in effect, the following Table embracing the conditions of the "Erie Experiments" with different pressures has been constructed; the steam under each of the assumed conditions of pressure, has been supposed to be cut off successively at $\frac{1}{10}$, $\frac{2}{10}$, $\frac{3}{10}$, - - - $\frac{10}{10}$ of the stroke, from the beginning.

Cut-off.	Cost of a Net Horse-power per hour in Pounds of Water.					
	$p = 2{\cdot}43$ Atmos. = 35·7 lbs.	$p = 3$ Atmos. = 44·1 lbs.	$p = 4$ Atmos. = 58·8 lbs.	$p = 5$ Atmos. = 73·5 lbs.	$p = 6$ Atmos. = 88·2 lbs.	$p = 9$ Atmos. = 132·3 lbs.
$\frac{1}{10}$	81·21	73·50	67·59	63·91	61·68	57·52
$\frac{2}{10}$	47·35	45·00	42·92	41·52	40·65	38·30
$\frac{3}{10}$	39·53	37·60	36·52	35·51	34·64	33·08
$\frac{4}{10}$	36 96	35·57	34·39	33·56	32·91	31·45
$\frac{5}{10}$	36·50	35·28	34·19	33·26	32·55	31·28
$\frac{6}{10}$	37·26	36·15	35·21	34·51	33·66	32·11
$\frac{7}{10}$	38·89	37·69	36·52	35·68	35·42	33·57
$\frac{8}{10}$	41·85	40·09	39·20	37·79	37·53	36·05
$\frac{9}{10}$	44·63	43·58	42·00	41·06	40·46	38·91
$\frac{10}{10}$	51·16	46·91	45·94	45·09	40·10	42·27

The diagram, Fig. 3, exhibits the law which governs the cost of net power, as determined by our formula (13)—and shows how nearly the results of theory, as we have applied it, agree with those of careful experiment. The ordinates of the curves represent the costs of a horse-power at the corresponding points of cutting off; the upper curve is

constructed in accordance with the results given by (13), under the conditions of the "Erie Experiments;" the lower curve with the results for $p=9$ atmospheres $=132{\cdot}3$ pounds; and the middle curve with the results of the "Erie Experiments."* In the last case, the numbers represented by the ordinates which determine the curvature, are taken from line 29, Table I, facing page 100, in Chief Engineer Isherwood's "Experimental Researches in Steam Engineering;" the points of cutting off, in these "Experiments," were $\frac{1}{12}$, $\frac{7}{10}$, $\frac{4}{9}$, $\frac{3}{10}$, $\frac{1}{4}$, $\frac{1}{5}$ and $\frac{4}{45}$; and the corresponding costs, in pounds of steam per net horse-power, per hour, 42·971, 37·662, 36·135, 39·357, 39·202, 43·803 and 60·53 respectively.

FIG 3



Vertical Scale, $1'' = 20$ *pounds.*

It will be observed that, as regards the measure of expansion which insures the greatest economy, the results obtained by the use of our formula fully confirm the correctness of the conclusions of Chief En-

*The dotted curve has been added, representing the expenditure of *fuel* in the "Erie Experiments;" *i. e.*, its ordinates represent the costs of a horse-power, when the steam was cut off at the points at which they are erected.

gineer Isherwood; it will also be observed that for points between $\frac{3}{16}$ and $\frac{7}{16}$ of the stroke, our theoretical results are nearly identical with the experimental results; and hence, since nearly all the points of cutting off employed in practice are embraced within the limits specified, it seems that we are justified in making the assumption that the formula will, in all practical cases, give results which may be relied upon as being practically correct. Again, since the point of cutting off which insures the maximum economy is the same for steam of 2·43 and 9 atmospheres, it may be assumed that it will be the same for all pressures between those limits.

It should be remarked also, that where the experimental results differ from those given by the formula, the experimental cost is *less* than the theoretical; hence if provision be made for the evaporation of the theoretical quantity of water for a given power, the development of the required power will always be realized.

Under the conditions upon which the "Erie Experiments" were made the formula indicates that the maximum gain, in net power, that can be realized from expansion is

$$\frac{51{\cdot}16 - 36{\cdot}5}{56{\cdot}16} \times 100 = 26{\cdot}11 \text{ per cent. of that developed when the steam is used without expansion.}$$

According to the experimental results, the maximum gain due to expansion was probably (see Fig. 4)

$$\frac{46{\cdot}7 - 36{\cdot}235}{46{\cdot}7} \times 10 = 22{\cdot}41 \text{ per cent.}$$

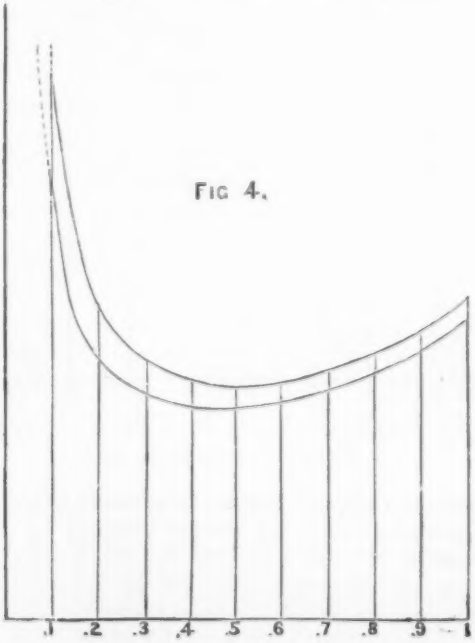


FIG 4.

Vertical Scale, 1″ = 30 pounds.

If we take ordinates of the dotted curve—of fuel—we shall obtain for the maximum saving in fuel, a result identical with that first found, from the results given by the formula (13). This is evident from the fact that the ordinates of the two curves, at full stroke, and at the point of minimum cost, are identical.

For the purpose of exhibiting the effect of clearance upon the measure of expansion due to the maximum economy, the following table—containing the costs for different values of c,—other things being the same as in the Erie Experiments—has been constructed: the numbers in the Table being obtained by substituting different values of c, in (13).

Cut-off.	Cost of a Horse-power.			
	$p=35{\cdot}7$ (1) $c=2$ per cent.	$p=35{\cdot}7$ (2) $c=5{\cdot}8$ per cent.	$p=35{\cdot}7$ (3) $c=8$ per cent.	$\frac{(3)-(1)}{(3)}\times 100$
$\frac{1}{16}$	70·58	81·21	89·37	21·25
$\frac{2}{16}$	42·37	47·35	50·15	15·51
$\frac{3}{16}$	36·27	39·53	41·43	12·45
$\frac{4}{16}$	34·33	36·96	38·44	10·69
$\frac{5}{16}$	34·34	36·50	37·85	9·27
$\frac{6}{16}$	35·12	37·26	38·26	8·21
$\frac{7}{16}$	36·93	38·89	39·97	7·61
$\frac{8}{16}$	39·92	41·85	42·83	6·79
$\frac{9}{16}$	42·49	44·63	45·59	6·78
$\frac{10}{16}$	49·33	51·16	52·21	5·52

The results in columns (1) and (3) of the Table, are represented graphically in the diagram, Fig. 4, which shows that by diminishing the clearance space, the absolute cost of the power is materially reduced; while the measure of expansion which insures the best results, becomes slightly greater than when the clearance is larger; or, which is the same thing, the best point of cutting off is slightly nearer the beginning of the stroke, when the clearance is small.

If, in any case—having calculated the costs of a horse-power for different points of cutting off—it be desired to determine the costs for a different pressure, other things remaining the same, the labor may be considerably reduced by tabulating the values of the factor

$$\left[\frac{a}{a+c}+hyp.\ log.\ \frac{l+c}{a+c}\right],$$

in (13); which, it will be observed, is constant for all pressures.

The following Table contains the different values of this factor, for clearances, from 1 to 8 per cent. of the cylinder:

Cut-off.	c = 1 per cent.	c = 2 per cent.	c = 3 per cent.	c = 4 per cent.	c = 5 per cent.	c = 6 per cent.	c = 7 per cent.	c = 8 per cent.	c = 5·8 per cent.
1/16	3·126	2·973	2·839	2·719	2·613	2·516	2·429	2·348	2·584
1/8	2·523	2·443	2·372	2·309	2·235	2·163	2·118	2·064	2·186
3/16	2·159	2·096	2·042	1·983	1·956	1·913	1·873	1·835	1·923
1/4	1·877	1·841	1·805	1·769	1·736	1·704	1·673	1·644	1·71
5/16	1·663	1·635	1·608	1·582	1·556	1·535	1·507	1·483	1·538
3/8	1·487	1·465	1·443	1·423	1·402	1·380	1·366	1·345	1·381
7/16	1·339	1·326	1·302	1·286	1·269	1·257	1·245	1·225	1·259
1/2	1·209	1·194	1·178	1·166	1·152	1·139	1·127	1·113	1·139
9/16	1·093	1·089	1·071	1·060	1·047	1·036	1·025	1·015	1·037
5/8	0·999	0·980	0·971	0·961	0·952	0·943	0·934	0·926	0·945

In conclusion it should be stated, that owing to the time and labor required, the numbers in the several tables that have been constructed in connexion with the discussion of this subject, have not been systematically verified; but in view of the great care which has been exercised in making the computations, to avoid errors, the writer does not hesitate to express the confident opinion, that whatever trifling errors may have crept in, have not sensibly affected the results; indeed, the uniform regularity of the curves constructed with the results —so far as curves have been constructed—is evidence of itself that appreciable errors have been avoided: however this may be, there seems to be no reasonable ground for doubt in regard to the conclusiveness of the proof of the correctness of Mr. Isherwood's "peculiar" theory—at least, so far as *economy* is concerned.

Naval Academy, Newport, R. I., April 30, 1864.

For the Journal of the Franklin Institute.

On the Steam-boiler Explosion at Cornelius & Baker's Works, Philadelphia, April 25, 1864. By JOHN W. NYSTROM.

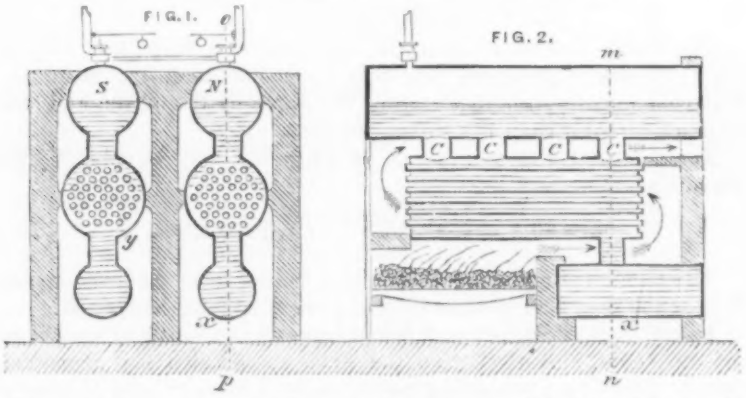
It is proposed to explain how the steam-boiler explosion happened at the establishment of Cornelius & Baker, Cherry street below Ninth, Philadelphia, on the 25th of April, at 7½ o'clock in the morning. Being one of the jury, I felt at liberty to examine the case more carefully than I probably would have otherwise done.

The construction of the boilers is shown by the accompanying figs. 1 and 2. The lower cylinders are mud-drums, the middle ones the returning tubular boilers and the steam-drums above, with connexions *c*, *c*, *c*.

Fig. 1 is a section through *m*, *n*, fig. 2, and fig. 2 is a section through *o*, *p*, fig. 1.

The dimensions of the boilers are as follows:

	Diameter.	Length.	Cubic Feet.
Mud-drum, . . .	30 ins.	6 ft.	30
Returning tubular boiler, .	41 "	10 "	68
Steam-drum, . . .	36 "	14½ "	100
Connexions, *c c c c*, . .	13 "	8 ins.	2
Cubic contents of each boiler, ...			200
" two boilers, . . .			400
" two steam-drums, . . .			100
Water in the two boilers, . . .			300



The working pressure of steam has averaged 80 lbs., but at the time of the explosion it was said to be only 65 lbs., which answers to a temperature of 315°. The total units of heat in both boilers was 4782660 in the steam and water, which, divided by Joule's equivalent, gives a concentrated force of 6200 horses. The heating surface of the boilers was 1200 sq. feet; fire-grate about 24 sq. feet. The heads of the steam and mud-drums are of cast iron 1¾ inch thick.

When steam boiler explosions take place, the enclosed volume of water W, of temperature T, will resolve itself into v volumes of boiling hot water of temperature t, and V volumes of temperature $6{\cdot}5\ t$ will be converted into steam.

Before. Explosion. After.

$$\mathrm{W\,T} = v\,t + 6{\cdot}5\mathrm{V}t. \quad (1)$$

and $$\mathrm{W} = v + \mathrm{V}, \quad (2)$$

of which $$\mathrm{V} = \frac{\mathrm{W}\,(\mathrm{T} - t)}{5{\cdot}5\ t}. \quad (3)$$

In the case before us, we have been told that the pressure of steam was 65 lbs. to the square inch at the time of the explosion, which answers to a temperature of $\mathrm{T} = 315° - 32° = 283°$. I have found by

calculation that the two boilers contained $w = 300$ cubic feet of fresh water, the temperature of which is 212° when at boiling point, or $t = 180°$ above the freezing point. We have by the preceding formula (3),

$$v = \frac{300\,(283° - 180°)}{5{\cdot}5 \times 180°} = 31$$

cubic feet of water suddenly converted into steam, and mixed with $v = 269$ cubic feet of boiling hot water, which will form a destructive force of $H = \frac{31 \times 180° \times 5{\cdot}5 \times 62{\cdot}5}{772} = 2485$ horses.

The destructive energy of the $w = 100$ cubic feet of steam of $T = 283°$, and volumes co-efficient $k = 362$, will be only

$$H = \frac{wT}{2{\cdot}22\,k} = \frac{100 \times 283°}{2{\cdot}22 \times 362} = 34{\cdot}7 \text{ horses.}$$

The steam and water being in the form of a foam, not only acts with its elastic pressure, but with its momentum, the same as in Giffard's injector, where we know the force of the steam and water is much greater than the steam pressure.

The destructive momentum of an explosion may be correctly measured by

$$H = 80\,v = \frac{1{\cdot}7777\,w\,(T - t)}{t}, \text{ horses.} \quad . \quad . \quad . \quad (4)$$

The numerous and clear indications traced from the accident, enables me to give a very clear idea of how it actually happened.

I shall first explain it as if I had been on the spot and seen it with my own eyes, and then give the data upon which my argument is based. Should my reasoning not be clear, I hope to hear it discussed at the next monthly meeting of the Institute, so that, if possible, nothing will be left in mystery.

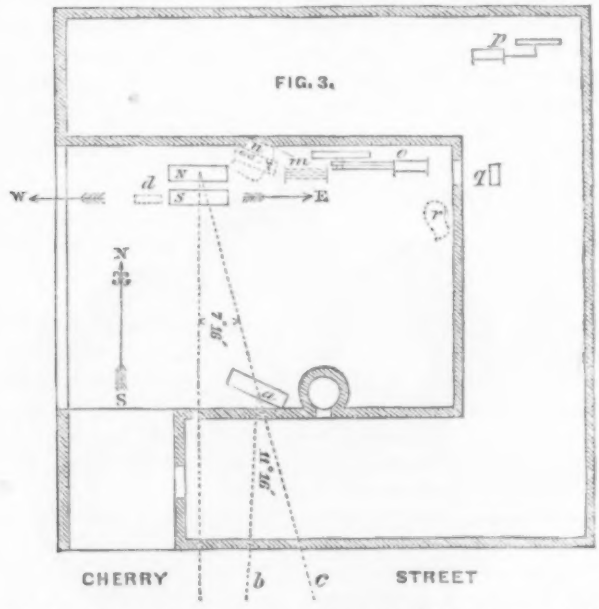
The mud-drum in the northern boiler was the first that gave way and caused the explosion. It burst near the middle about 4 ins. from the centre line, at *x*, figures 1 and 2; the numerous fragments of the mud-drum bruised and cut several holes in the shell of the tubular boiler above it, and also one hole in the south boiler at *y*, fig. 1.

The before calculated collective force in the boilers, is now suddenly relieved; its momentum finds the weakest part, first in the tubular boiler next to the bursted mud-drum, to be in the connexions *cc*, *cc*, where nearly half of the strength of the shell is cut away. It blew wide open the whole length, acted uniformly on the steam-drum above, threw the latter up with a velocity of 254 feet per second, or 173 miles per hour, into the air, at an angle of 47° 30′ south, by 7° 16′ east, struck the cornice of the main building at *a*, fig. 3, 60 ft. 4 ins. above, and 58 ft. 2 ins. horizontally from its home N. When it struck, it was at an angle of about 20° to the building, with the gauge-cock, or manhole end foremost. This obstruction caused it to deviate from its original course N *ac*, about 11° 16′, to *a b*, or south by 4° west, as shown by the figure; continued to a height of 272 feet, the vertex of

the parabola. In the flight it made $1\frac{3}{10}$ turns in the length, and arrived with a velocity of 237 ft. per second, from an altitude of 51° 30′, in the Penn stable, Market street, just 1000 ft. from home. The drum seemed to have been horizontal and parallel with north and south, when it struck the roof of the stable, falling with the south end on a strong beam in the floor, broke through with the north end into the cellar, where it injured slightly one man, and killed a horse, rested in a position of about 55°. The time of flight was about 5·75 seconds. Had the steam drum continued unobstructed in its original course, N *a c*, figure 3, it would have fallen in Eighth street, between Market and Chestnut.

Let us now go back to the factory and see the next of the explosion.

FIG. 3.



The tubular boiler burst open as described, the force of the steam and water acting in a general radiating direction below the fire on the grate in through the doorway, *q*, fig. 3, where it set fire to a box of wooden shavings, about 40 feet from the boilers; the tubes with the tube plates *m*, followed the fire about 20 feet towards the new steam engine, *o*. Three men were killed in this operation.

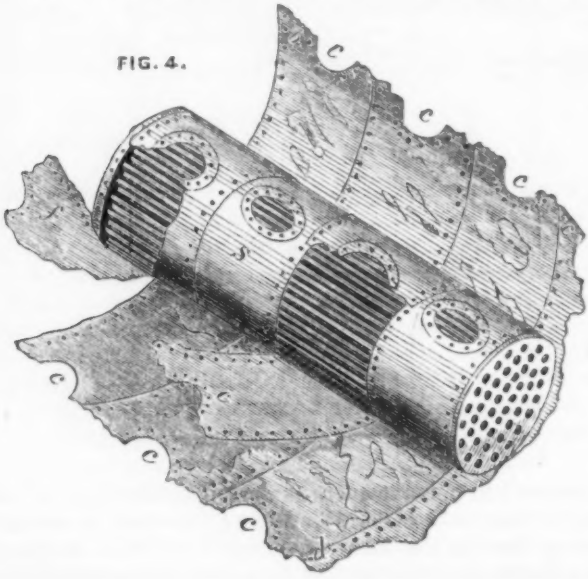
Now in reference to the boiler S, which, by the shock of the former explosion, was injured in the connexions *cccc*. The second ring *e*, fig. 4, gave way first, when the momentum in the steam and water broke the steam drum above it into two parts; blew the one east, nearly horizontal to *r*, where it damaged the stamping establishment. The fourth ring *f*, burst simultaneously to that of *e*; the steam and water acted to throw the west part of the steam drum straight up, while the longitudinal force acted to throw it horizontally due west; the result-

ant of the two forces caused the drum to ascend at an angle of 31°, and a velocity of 306 feet per second, or 208 miles per hour, attained an altitude of 228 feet, descended in a bottling establishment near to Twelfth street, with a velocity of about 291 feet per second, at an angle of 37° 10′, and 1350 feet from home s. The drum ricocheted a distance of about 52 feet from where it struck the floor. A man was killed by a piece of wood which the steam drum broke loose from the roof in the bottling establishment. The time of flight was about 5·4 seconds.

The distance, 1000 feet to the Penn stables; also, the 1350 feet to Twelfth street, was kindly furnished by Mr. D. H. Shedaker of the Department of Surveys.

Let us now return to the factory and see the balance of the explosion. The shell of the north boiler now being torn wide open and in flight, the south boiler followed and fell into the former at *n*, fig. 3, a distance of about 12 feet north-east from home, the position in which it was found after the explosion, and represented by figure 4.

FIG. 4.



The mud-drum of the south boiler was new, and not injured by the explosion: it moved backwards some 10 feet and rested in the position *d*, fig. 3. This mud-drum had been in use only a few months; the old one was found defective and therefore condemned.

The boilers have been in use about two years and a half.

I have in my possession samples of the exploded boiler and mud-drum, which it is my intention to deposit in the archives of the Franklin Institute.

It will be seen that the piece of iron from the mud-drum taken

from the bottom where it first burst, is corroded down in one place to $\frac{1}{32}$ of an inch in thickness; several square feet in the bottom where it burst did not average more than $\frac{1}{16}$ of an inch; othewise the iron appeared to be of good quality. The inside of the drum shows plainly an excess of corrosion, by small holes eaten nearly through the metal.

In the Coroner's inquest, the engineer of the exploded boiler testified to having cleaned, sounded with a hammer, and with a light examined the inside of the exploded mud-drum, about three weeks before the accident, when he considered it in good condition.

The thickness of iron in the tubular boiler averaged a quarter of an inch, but in some places between the joints *c*, *c*, *c*, *c*, where it burst, it is as low as $\frac{3}{16}$ of an inch. The length of the boiler being 10 feet, of which four holes of 13 inches each or 52 inches is cut away, leaving only $120 - 52 = 68$ inches by $\frac{1}{4} = 17$ square inches to resist a pressure of $\frac{1}{2} \times 120 \times 42 \times 80 = 201600$ pounds, divided by 17 will be 11860 or 5·3 tons per square inch, which cannot be considered safe in this peculiar case.

When steam is fast generated it cannot rise sufficiently fast through the connexions to keep the water in contact with the upper part of the tubular boiler, subjected to a very high heat, which considerably reduces the strength of the metal.

The nature of those joints are such, that they require not only the very best quality of iron, but also the very first class workmen in turning the flanges, and with the greatest possible care, its strength will be but a small fraction of that of a solid sheet. Therefore, a boiler of nearly double the diameter, and with the same thickness of metal not cut, would have the same strength.

The strength of the mud-drum, until the explosion, had likely been assisted by the lateral strength of saturated scales and rust, filling up the small cavities in the iron. By some sudden change in temperature in the mud-drum, the scales and rust have likely cracked, and left the thin iron to resist the steam pressure, when explosion must necessarily take place, independent of height of water in the boiler.

It has been conjectured that the water had been low in the boiler when it exploded, but there is no positive indication of any iron having been overheated. A few tubes which had been torn from the boiler had indications of collapse, but no overheating; that collapse had likely been done by the momentum of explosion, (formula 4) which is quite a different force from that of the original steam pressure.

The boilers were fed by a No. 5 Giffard's injector, which was stopped a few minutes before the explosion took place; the engineer found by the gauge-cocks that there was plenty of water in the boilers.

Experienced engineers say that it is sometimes very difficult to observe the height of water in this kind of boilers; a glass water-gauge shows an oscillation of some 5 inches several times per second, accounted for by the imperfect circulation through the connexions *c*,*c*,*c*, which constitute one of their greatest defects.

Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.

From the Lond. Mechanics' Magazine, July, 1863.

[Report of the Chief Engineer, July 28, 1863.]

During the past month there have been examined 324 engines and 450 boilers. Of the latter, 17 have been examined specially, 11 internally, 55 thoroughly, and 367 externally; in addition to which, 3 of these boilers have been tested by hydraulic pressure. The following defects have been found in the boilers examined :—Fracture, 8 (2 dangerous); corrosion, 16; safety-valves out of order, 9 (2 dangerous); water-gauges, ditto, 2; pressure-gauges, ditto, 8; blow-out apparatus, ditto, 37; fusible plugs, ditto, 2; furnaces out of shape, 4; over-pressure, 1 (dangerous); deficiency of water, 1 (dangerous); blistered plates, 3. Total, 110, 6 (dangerous). Boilers without glass water-gauges, 2; without blow-out taps, 38; without back-pressure valves, 41.

It is gratifying to find that the number of "thorough" examinations of boilers, though not high during the past month, is steadily increasing. During the month ending June 26th last, as many as 104 were made in addition to 12 "internal," and 10 "special"—making 126, independently of the ordinary "external" examinations. This number is a greater one than has been reached in any previous month.

Explosions.—One explosion has occurred during the last month, of a very fatal character, to an ordinary mill boiler of the two-flued "Lancashire" class, by which 10 persons were killed and four others injured. This boiler was not under the inspection of this Association.

The dimensions were as follows—length 30 ft., diameter of the shell nearly 7 ft. 6 ins., and that of the furnace tubes—which were parallel throughout, and not strengthened by any hoops or flanges—2 ft. 8 ins.; the thickness of the plates in the shell and tubes, seven-sixteenths, in the flat end plates half an inch, each of them being strengthened with three gusset stays secured with double angle-irons.

The longitudinal seams in the shell were not laid in line, but disposed so as to break joint. The age of the boiler was about two years. It had not been tested by hydraulic pressure.

The boiler had been fitted with a single lever safety-valve, the valve being enclosed in a box bonneted over, from which the waste steam escaped through a discharge pipe, carried through the wall of the boiler-house. It had also been fitted with a glass water gauge—a feed-check and back-pressure valve combined, fixed to the front end plate, a little below water level—a blow out or mud tap, and a steam pressure gauge, of the dial class; but the boiler had no tap for fixing an indicator so as to check the accuracy of the gauge, and ascertain the actual working pressure with the steam up.

The boiler was rent into so many fragments by the explosion, that it was completely destroyed, while considerable damage was also done to the surrounding property. Both the furnace tubes were torn away from the end plates, as well as separated into two pieces, dividing at one of the transverse seams at the middle of their length. Three of

these lengths, weighing upwards of a ton each, were blown over a row of cottages, one alighting on the first floor of a dwelling beyond, having broken through the roof in its fall, the other two lengths falling at intermediate distances between these two rows of buildings; while the fourth fell on a cottage, carrying in the roof. The safety-valve weight, which was a ball of about 8 ins. diameter, was shot upwards, and on its fall, broke through a roof of a third cottage. The shell of the boiler had been torn up into so many small pieces that it was difficult to trace the course of the rents, and to determine where they had first commenced; but it may be remarked, that one of them ran through the manhole, which was not strengthened as it should have been by a substantial mouth-piece. These fragments of the shell lay scattered near the original seat of the boiler, while some were buried under the ruins. The end wall of the mill was blown down, and the various floors laid open, while the engine was completely buried in the *debris*. The chimney was gashed by a large rent, running up it for half its height, and stood tottering over the old seat of the boiler, so that approach was dangerous; while the ground surrounding was covered with bricks, and the ruins of the injured buildings. But it is difficult to convey an adequate idea of the ruin that had been produced.

The cause of the explosion has twice been investigated before a coroner's jury, conducted in each instance by a different coroner on account of the localities in which the deaths occurred. Scientific evidence was given in each case. At the first trial, one scientific witness gave it as his opinion that there were no traces of there having been any deficiency of water, but that the safety-valve had been deranged and inoperative; while at the second trial, another scientific witness thought that the safety-valve had worked quite "glibly," and that shortness of water had caused the explosion. A verdict of accidental death was brought in in each instance.

With regard to the explosion having arisen from shortness of water, it was given in evidence at the inquest that the gauge-glass was blown through, and plenty of water observed shortly before the explosion happened: the correctness of which was borne out by subsequent examination, since the flues were found to be coated with incrustation which overheating, had it occurred, would have disturbed; while, in addition, the furnace-crowns could not have retained their shape as they did, had the water been low.

As to the explosion being due to excessive pressure consequent upon the defect of the safety-valve, it is true that the spindle of the valve was bent, but it is a matter of opinion whether this did not become so subsequently to the explosion, and was its consequence rather than its cause. At the time of making my own examination, which was done immediately on the explosion being reported, there was no opportunity of seeing the safety-valve, since it was in the hands of the jury who were then engaged on the inquest—but I am informed, on good authority, that the injury was such as could not have occurred to the valve in regular work, while it was known to have been previously in good order.

But, apart from the condition of the safety-valve, there are other considerations affecting the view that the explosion was due to excessive pressure alone. There was no evidence to prove that the pressure exceeded 60 lbs. per square inch, and neither that nor twice the amount would have rent the shell had the material and workmanship been good; while from the fact that the flue-tubes were not collapsed, and the shell was rent into fragments—although the latter should have resisted twice the strain of the former—it is clear that the explosion did not result from simple over pressure.

It cannot be doubted that the plates were of very bad quality, one of them in the shell, situated at the top of the external flue had fractured through the solid when the boiler was at work a few months since, while it is reported that one of the scientific witnesses who gave evidence at the inquest stated—that merely with the blow of a brick he had broken off a piece of plate about 15 or 16 sq. ins. in area, and seven-sixteenths in thickness. The cast iron nature of the plates rendered them less adapted to withstand the tensile strain of the shell than the compressive one of the furnace tubes which therefore accounts for the shell having been broken to pieces, while the furnace tubes were uninjured, except by the effects of the explosion itself.

Such is the simple cause of this explosion. The evidence given at the inquest, as well as the examination of the furnace-crowns, forbids the conclusion that the explosion was caused by deficiency of water; while, further, the fact that the shell, which should have been stronger than the tubes, rent into a number of small pieces while the tubes did not collapse, shows that the explosion was not due to excessive pressure, but to the defective quality of the plates of which the boiler, on examination, was found to have been made.

In conclusion, the attention of our members may be specially called to the following points:—

The contradictory nature of the evidence too frequently admitted at coroner's inquests as to the cause of boiler explosions, of which the case above is an illustration.

The short-sighted economy of purchasing low-priced boilers, erroneously termed "cheap" which leaves the maker no alternative but to use plates of inferior quality, a practice not only detrimental to the interests of the steam user, but also unfair to the honest boiler-maker.

The importance of having all boilers thoroughly tested with hydraulic pressure; this had never been done with the boiler under consideration; had the test been applied, there can be little doubt that the inferior quality of the plates would have been detected, and the explosion prevented.

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[Report for August, 1863.]

From the Lond. Mechanics' Magazine, August, 1863.

During the past month there have been examined 313 engines and 401 boilers. Of the latter 6 have been examined specially, 9 internally, 45 thoroughly, and 341 externally, in addition to which, two of these boilers have been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 5 (1 dangerous);

corrosion, 14; safety-valves out of order, 7; water-gauges ditto, 9 (1 dangerous); pressure-gauges, ditto, 15; feed apparatus, ditto, 2; blow-out apparatus, ditto, 27; fusible plugs, ditto, 1; furnaces out of shape, 4 (1 dangerous); over-pressure, 3; deficiency of water, 1 (dangerous). Total, 88 (4 dangerous). Boilers without glass water-gauges, 3; without blow-out apparatus, 16; without back-pressure valves, 25. Nine explosions have occurred during the past month, from which 5 persons have been killed and 3 others injured. Not one of the boilers in question was under the inspection of this Association. A personal examination of three of these has been made subsequently to the explosion, while in the remaining cases this was prevented by distance. In one case the cause of the explosion was simply the dilapidated condition of the boiler; it had repeatedly been found to leak at the back end, both at the last plate at the bottom, as well as at the flat end one, and had in consequence, been temporarily repaired, from time to time, with bolted patches. Patches, when necessary, should always be riveted on, no reliance can be placed upon those merely bolted. At the time of the explosion there were three of these patches on the boiler, within 12 ins. of one another. The surrounding plate at length became so eaten away by continual leakage, that it was reduced in places to one-eighth of an inch in thickness, and in others to that of a sheet of brown paper, from which rupture ensued, underneath the boiler, at the back end, immediately over the mid-feather; the mid-feather, no doubt, accelerating the corrosion, by ponding the water, and holding it in contact with the plate, at the same time that it concealed the full extent of the injury. Competent inspection could not have failed to detect the dangerous condition of the boiler. The report concludes with suggestions as to the best mode of setting boilers.

[Report, September 29th, 1863.]

From the London Mechanics' Magazine, Oct., 1863.

During the past month there have been examined 319 engines and 471 boilers. Of the latter, 4 have been examined specially, 4 internally, 49 thoroughly, and 414 externally, in addition to which 1 of these boilers has been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 5 (2 dangerous); corrosion, 16; safety-valves out of order, 2; water-gauges ditto, 20 (1 dangerous); pressure-gauges ditto, 10; feed apparatus ditto, 2 (1 dangerous); blow-out apparatus ditto, 14; fusible plugs ditto, 8; furnaces out of shape, 1. Total, 78 (4 dangerous). Boilers without glass water-gauges, 3; without blow-out apparatus, 21; without back-pressure valves, 17.

Explosions.—Three boilers, not under the inspection of this Association, have exploded during the past month, from which four persons have been killed and three others injured. One of the boilers has been personally examined since the explosion, while this was prevented in the other cases by distance.

The first explosion, from which one person was killed and two others injured, happened to an agricultural boiler while at work at a farm,

driving a thrashing machine. It was not under the inspection of this Association.

The boiler which was about twelve years old, was a portable one, of the multitubular locomotive type, and was worked at a pressure of about 40 lbs. per square inch. It was stated at the inquest that the safety-valve worked freely, and that there was a due supply of water the explosion being attributed entirely to a defective plate in the fire-box, which had been eaten away by corrosion, until reduced to one-sixteenth of an inch in thickness. This plate had been previously repaired, and at the time of the explosion was cracked through, and though it had for some days been leaking in consequence, had yet been worked on in that state.

The owner of the boiler was brought in guilty of manslaughter, the jury adding that they thought the appointment of a government inspector to be highly necessary.

The second occurred to a new balloon or hay-stack boiler during the operation of testing at the maker's yard. It had not been constructed for raising steam for purposes of power, but was intended to be used as a chemical evaporating pan or still. It was not under the inspection of this Association.

The boiler—as another of similar construction and dimensions had recently been—was proved with steam, in order to test the tightness of the joints. The pressure, which appears to have been about 50 lbs., being raised, not by generating the steam within it by means of a fire underneath, but by communication with another boiler in work, to which it was temporarily connected for the purpose. Some five or six men were engaged upon it in caulking the seams at the time of the explosion, four of whom were blown to a distance from it; one of them, who was killed upon the spot, being thrown upon the roof of a house about 40 yards off, while two others died subsequently from the injuries received. The boiler was laid upon its side during the test, and gave way at the bottom, which was blown out entire, and thrown upon a roof about 10 ft. high and 13 yards distant, the shell rearing up on its dome end, and remaining in that position supported by a shear leg.

Its dimensions were as follows:—The height was 11 ft., the dome, from the appearance of which the term balloon boiler probably arose, was 9 ft. 3 ins. in diameter, and the base 8 ft. 9 ins., while the cylindrical sides were drawn in to 7 ft. 9 ins. in the waist. The bottom, like that of a bottle, was concave, as is usual in these boilers, and rose 18 ins. at the centre, in order to enable it to resist the downward pressure, being connected to the sides of the shell by a 3-in. angle iron, half an inch thick. The plates, which were from seven-sixteenths to half an inch in thickness throughout, were some of them second-hand, those forming the dome being new, the remainder having been used in a boiler before. They had, however, been worked to their new shape, their edges sheared, and the holes punched afresh. The rivets, which were three-quarters of an inch in diameter, were centred from $1\frac{7}{8}$ ins. to 2 ins. apart, and the general workmanship appeared satisfactory.

The rent between the bottom and sides of the boiler had occurred,

for the most part, at the lower ring-seam of rivets in the cylindrical portion of the shell but not altogether so, some portion of the rent running through the rivet holes at the outer edge of the circular bottom plate; while, from the upward position in which the latter was thrown by the explosion, it appeared most probable that the rent had commenced at that part of the boiler which lay nearest the ground at the time of the explosion, and thus from the position of the fractures, must have started at the cylindrical part, and not at the bottom plate. The reason of this is not very apparent—since there were two other ring-seams of rivets in the cylindrical portion of the boiler which were quite uninjured, although subjected to the same direct pull, which, after allowing for the rivet holes, did not amount to two tons per square inch of metal, added to which, the longitudinal strain thrown upon these circular seams in cylindrical boilers, is only half of that which occurs in the transverse direction, so that it is difficult to account for the rent selecting the lower ring-seam of rivets, or indeed for its occurring at all.

Whether, however, the rent in question was due to some undetected flaw in the iron, or whether the plates had been crippled in being brought together, which is too frequently the case, or whether an unfair strain was caused by the springing of the bottom plate, which, although arched eighteen inches in the centre, was yet flat as compared with the hemispherical top; or whatever may have been the cause that started the rent, one thing is certain, that the application of the hydraulic test would have detected and exposed the weakness, prevented the explosion, and saved the three lives. It is, therefore, again earnestly recommended that in all similar cases, this precaution should be adopted; and it is trusted that it will not be necessary for any further additions to be made to the list of fatal explosions—already sadly too long—before the adoption of the simple and inexpensive hydraulic test becomes universal.

A Magnetic Discovery.

From the London Mechanics' Magazine, Feb., 1864.

Dr. A. von Waltenhofen has communicated to *Dingler's Polytechnisches Journal*, an account of a curious magnetic discovery which he has recently made. It is a well-known fact that the magnetism of an electro-magnet does not entirely disappear with the cessation of the magnetizing current. Dr. A. von Waltenhofen has, however, observed that the amount of this residual magnetism, as it is called, is dependent upon the manner in which the current is interrupted. If this interruption takes place suddenly, the residual magnetism is much less than when it takes place gradually. A still more interesting circumstance has been observed by him—viz: that the residual magnetism obtained by suddenly breaking a very strong current, is sometimes of an opposite nature to that previously existing in the electro-magnet. This fact, which he has hitherto only noticed in very soft iron, is of great interest, inasmuch as it furnishes a new and simple proof that magnetism is not caused by the separation of two fluids, but by the motion of magnetic molecules, to which is opposed a certain amount of frictional

resistance. With much ingenuity he compares the state of each magnetic molecule of the electro-magnet to that of a spring which is bent back. If the spring be suddenly released, it will return very nearly to its original position, or even go beyond it. On the other hand, if it be released gradually, it will stop at a point still further removed from its original position.

Voltaic Electricity—New Caloric Battery.

From the Lond. Mechanics' Magizine, Feb., 1864.

At the last meeting of the Inventors' Institute, (Capt. J. Selwyn, R.N., in the chair,) Mr. James Dickson read an interesting paper "On Certain Inventions for insuring the Economical and Efficient Production of Voltaic Electricity for Lighting Streets and other Purposes." The object of the paper was to explain the means by which electricity could be readily and economically produced. The history of voltaic electricity was carefully traced from the time of Volta, from whom this form of electricity took its name, to the present time, special mention being made of Grove's, Smee's, the Maynooth and other batteries which from time to time, have been looked upon as vast improvements upon then existing apparatus. The theories of Mayer and Joule were referred to, as well as the researches of Professor Tyndall, whose "Heat as a Mode of Motion" contains so much valuable information upon the subject. He considered that the rapidity of the vibration of the atoms in a conductor was exactly in proportion to its conducting power, and explained that, whilst a battery was producing light and heat, less material was being consumed than when the battery poles are directly connected with each other. Mr. Dickson's battery was described as one of the hot-class—the sulphuric acid was heated to 600 degs. Fahr. He claims by his mode of applying heat to be able to use iron and other cheap metals, instead of the dear ones—zinc, copper, &c. The relative mobility of the atoms of an electrolite determined, he considered its force rather than its specific gravity. When oil of vitriol was heated to 350 degs. Fahr. only, the electric action is less powerful than when heated to 600 degs. Fahr., probably owing to the waves being less rapid. With the necessary percolating apparatus he was convinced that his battery would be successful for lighthouse purposes. He considered 15 to 20 of his cells equal to 20 to 22 cells; 3 of his cells are not equal to 2 of the nitric acid cells, but the increment in his battery was greater. Grove's battery cost 1s. 5d. to produce the same amount of electricity as that produced for 10¼d. by Dickson's. Comparing the lightning powers, 11¼d. with the caloric battery, will produce the same amount of light as 1s. 5d. by Grove's. He declared that the sulphur liberated at the negative poles could be reconverted into sulphuric acid to the extent of 19-20ths. The oil of vitriol, during the working of the battery, becomes combined with water, but the acid is easily and cheaply reconcentrated. In Smee's, Daniel's, and Grove's battery, the sulphate of zinc cannot be recovered, whilst in his caloric battery the recovery was not difficult.—The chairman expressed the

fear that the invention promised so much that he was no more likely to perform it than to obtain perpetual motion; indeed, if the invention were not overstated, they would certainly be nearer perpetual motion than they had ever been before.—Mr. Varley suggested that as the principle feature in the invention appeared to be the heating of the matrials, it was not impossible that it might be as great a step in advance as the introduction of the hot-blast in the manufacture of iron; this of course remained to be seen.—The new light will be exhibited at the meeting, on February 18, when an opputunity will be afforded for examining the caloric battery in operation.

Explosion of a Steam-Boiler in the establishment of Merrick & Sons, Philadelphia—Verdict of the Coroner's Jury.

In examining into the cause of the late disastrous explosion, we find the following facts presented to us:

A boiler built upon a certain plan, had been in use in the establishment for seven years; it had proved economical in its consumption of fuel, and occupied but little space; as, however, it had been in constant use for the above number of years, it was deemed advisable by the firm to construct a new boiler, which might either work alternately with the old one, or take its place in supplying them with steam.

The older boiler had never given them any trouble, except in one part called the water-legs, in the back part of which, that is, back of the bridge wall, sediment had collected, and caused the iron to rust out.

Satisfied with the efficiency of the first boiler, the new one was designed upon the same general plan as the old one, every precaution being taken (as was supposed) to make it strong and durable: and to obviate the trouble arising from the accumulation of sediment in the water-legs, a modification was made in that part.

The second boiler being completed, was tested and found to leak in a certain place. This leak was mended, and after several trials the boiler was pronounced tight and ready for use. The boiler was then fired, and furnished steam for the establishment, at first in connexion with the old one, and finally for several days by itself.

On the morning of April sixth, the day of the explosion, the leak was found to have re-opened to such an extent as to cause uneasiness as to the water-supply, on the part of the foreman of the establishment, Mr. Danby, who gave orders to have steam raised in the old boiler, and to draw the fires in the new one.

While these orders were being carried out the explosion occurred.

Examining into the competency of the man in charge of the boiler, the conviction is forced upon us that he was well qualified for his situation, and was a good, careful man.

Abundant testimony has also been given to prove that the pressure of steam at, or immediately before, the explosion was not more than fifty-seven pounds, and that the boiler was well supplied with water.

The usual theories of explosions, namely low-water, sudden priming

or forcing up of water into the heated, steam, &c., seem not to be applicable to the present case, and we are forced into a consideration of the form of this boiler and the possible existence of some weak point which did not exist in the old one.

This boiler is of form similar to those used on steam vessels, and having flat sides and an arched roof, is mainly dependent upon stays for its strength. (See Plate IV.)

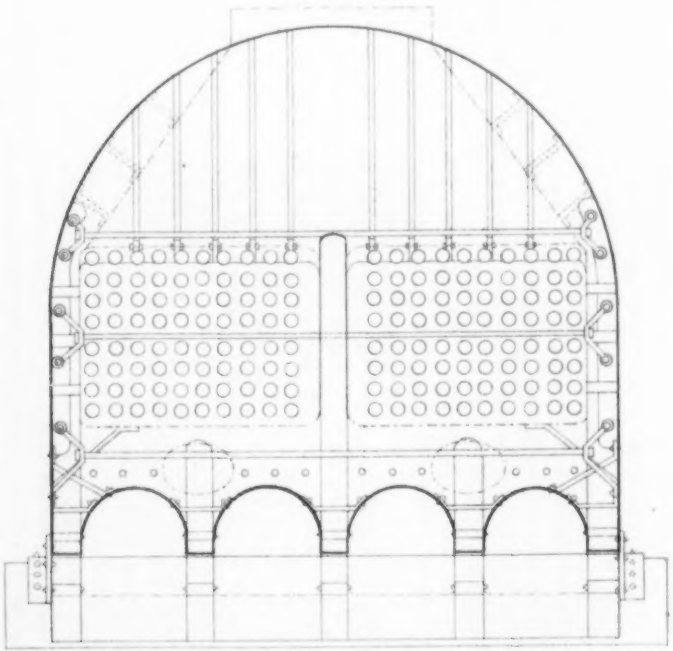
The sides seem to have been abundantly supplied with these stays, and to have been but little injured by the explosion, while the whole of the bottom part, containing the furnaces has been violently rent from the sides, and projected in one direction, while the main part of the boiler was thrown in an opposite direction.

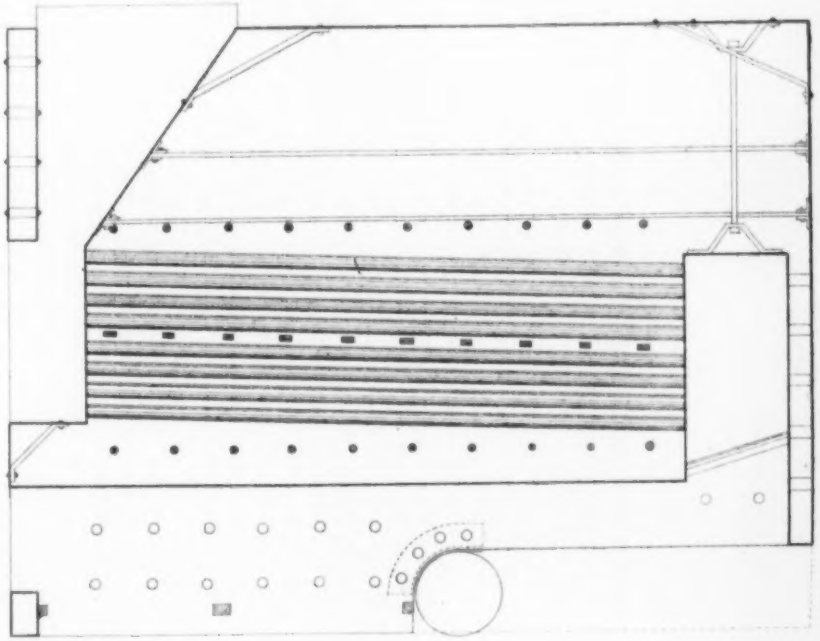
The bottom or furnace part of the boiler consists of a series of arched passages used as furnaces; said passages being twenty-one inches wide, semicircular on the top or crown, and stayed from one to the other by a series of iron braces. The parts between the arches are what have been termed water-legs. These water-legs on the old boiler extended from the front to the back of the boiler, thus forming powerful beams, thirty inches in depth, to resist the pressure of the steam tending to push the bottom out of the boiler. At the front they are connected by a water-space below the doors of the furnaces, and at the back by a water space extending to the bottom ; and thus were firmly united, and formed as it were, a floor supported by beams about thirty inches deep, five inches wide, and only thirteen feet long, which were, moreover, tied together top and bottom, at both ends to prevent their spreading at the bottom from the pressure above ; a form admirably adapted to carry the load placed upon it.

In the new boiler we find that the beams upon which depend the stability of the bottom, were not continued from end to end of a uniform depth, but by the cutting off of the part which was filled with sediment in the old boiler, have been reduced to a depth from the crown to the bottom of but thirteen inches for a distance of one-half of their entire length. Hence the floor-beams, as it were, are reduced to less than one-half the depth of those in the old boiler, namely from thirty inches to thirteen inches in the centre of the boiler bottom. The most valuable part of the beams having been removed by this operation, and the main support of the crown sheets taken away, no additional stays were put in to compensate for this weakness.

Without going into any calculation of the strength of the floor of the boiler, we see that it is not half as strong as the old one, and has yielded under a pressure of only fifty-seven pounds per square inch.

That the yield took place at this part, in the very centre of the boiler bottom, is manifested by the leak, which persistently appeared at this very part, where a rupture should have begun if the floor was too weak. This leak was mended from time to time, but, on the day of the explosion, had increased to such an extent as to endanger the water-supply, and to cause the order to be given for discontinuing the use of this boiler, unfortunately too late, although this order was promptly given, and was in course of execution.





Scale 1 inch to 3 feet

Your jury believe that the diminished strength which resulted from the change escaped the notice of the constructors, and that the making of the new boiler and its management afterwards, were designed as precautionary measures, and were intended to avoid the very disaster which has fallen upon them and the unfortunate victims.

COLEMAN SELLERS,	JONATHAN CHAPMAN,
HENRY MORTON,	JOHN F. FRAZER,
JOHN AGNEW,	GAVIN H. WOODWARD.

Substitutes for Gutta-Percha.

From the Journal of the Society of Arts, No. 589.

The following particulars in reference to the *Balata*, stated in last week's *Journal* to have been sent over by Sir W. Holmes from British Guiana, have been received. Sir William Holmes says:—

By the last mail I received your "Subjects for Premiums" for the session of 1863-64.

My object in addressing you is to advise, that by this packet I forward a box containing samples of *Balata* in its milky state, and also dried or coagulated. I entertain the hope that these samples fully meet the requirements of the 77th Section of your list of premiums, in reference to a substitute for india-rubber or gutta-percha, but I also trust it will be found more valuable than india-rubber or gutta-percha by themselves, possessing much of the elasticity of the one and the ductility of the other, whilst it requires a much higher temperature to melt or soften it.

After these preliminary observations, I must go somewhat into detail. I was Commissioner, representing the colony of British Guiana, at the International Exhibition of 1862. Amongst the varied contributions from the colony was a morsel of the dried milk of the bullet-tree (*Sapota Mulleri-Miq.?*); it weighed perhaps half a pound. Amongst the numerous individuals who visited the Guiana department was Mr. Chas. Hancock, who is well known in the gutta-percha trade. This gentleman was struck with the appearance of the specimen, and obtained a portion for experiment; he reported favorably as to its utility and value, a result most gratifying to me, as I had received adverse opinions from less experienced persons. This happened, I think, in July, 1862. From that time to the present I have been engaged in investigations how to produce the material cheaply, and how to dry or coagulate it rapidly. In both particulars I believe I have succeeded so far as to warrant the importation of steam machinery to be applied to its extraction, and by a fortunate accident I have discovered how to dry or coagulate it, preserving the characteristic of elasticity at a single operation, by the addition of a simple ingredient not very costly.

The samples forwarded consist of—1st, a bottle of milk as extracted from the tree by tapping; 2d, of lumps or cakes, weighing together five lbs., of this milk prepared for the market; and 3d, some balls to show, by the result of the process discovered by me, that this material

is nearly as elastic as india-rubber; indeed, as far as I can judge, *Balata* cannot be rivalled by either that material or gutta-percha, possessing, as I before stated, much of the elasticity of the one and the ductility of the other, without the intractability of india-rubber or the brittleness and friability of gutta-percha. Amongst the useful properties possessed by *Balata*, I believe the fresh milk of the bullet-tree to be the best water-proofing material yet discovered, and further that, *Balata*, as prepared by me, will supply the great want of the day, as a good insulating medium for telegraphic purposes.

The bullet-tree is a magnificent timber tree, often squaring 30 to 40 inches, and is much used, especially in Berbice, for building purposes. The milk, when quite fresh, is so bland that it is sometimes used as a substitute for cow's milk, and the fruit is delicious.

The bullet-tree abounds in many districts of the colony; indeed I may say, throughout this part of South America, and I trust that *Balata* may ere long be added as an important item to the exports of the colony, and tend to prove that the International Exhibition of 1862 has, in this instance, also been productive of practically useful results, not only to this community, but to the interests of science and art generally.

I annex a letter from the Honorable William Walker, Government Secretary of the colony, and Chairman of the Corresponding Committee of the Royal Agricultural and Commercial Society of British Guiana, which is affiliated to the Society of Arts, in order to fulfil the conditions specified in the prospectus.

Substitute for Gutta-Percha.

From the London Artizan, March, 1864.

At a meeting of the French Academy of Sciences, M. Serres gave an account of the *Valata*, a shrub which abounds in Guiana, and affords a juice which he asserts is superior, for many purposes, to gutta-percha, but especially as an insulating material for enveloping telegraphic wires. The milk or juice is drinkable, and used by the natives with coffee. It coagulates quickly when exposed to the air, and almost immediately when precipitated by alcohol, which also dissolves the resin of the *Valata* juice. All the articles made with gutta-percha can be made with the sap of the *Valata*, and it has no disagreeable smell. When worked up it becomes as supple as cloth, and more flexible than gutta-percha. M. Serres exhibited a number of articles manufactured of *Valata* milk. Up to the present time it seems, from M. Serres' account, not to have become an article of commercial export.

Method of Making Cast Steel. By M. Galy Cazalat.

From the London Practical Mechanic's Journal, Sept., 1863.

This metallurgist has communicated to the Academy of Sciences at Paris, that by passing through fused cast iron at 1400° centigrade, numerous capillary jets of superheated steam, he is enabled rapidly

and fully to remove the carbon which is taken up by the hydrogen of the decomposed water, and also to burn out, by the oxygen liberated from the water, the silicon, while the sulphur, the arsenic, and even the phosphorus are removed in combination with the hydrogen. Should this prove to be so, we may have an auxiliary to Bessemer's method, at least, and possibly even a substitute for it. We await, however, fuller details and confirmations.

Preservation of Corn from Fermentation.

From the London Mechanics' Magazine, January, 1864.

An experiment was lately made in Paris for the preservation of corn from fermentation and the attack of insects by enclosing it in a metal vessel and exhausting the air. The experiment was made in the presence of 40 persons, and succeeded perfectly. Ten hectolitres of wheat were placed in a metal vessel, and the air was exhausted. The vessel was opened after 15 days, and the weevils, which were seen quite lively when the wheat was placed in the vessel, had quitted their cells and were dead. They were warmed but did not stir. Being placed on white paper, they were crushed and reduced to powder, without leaving any stain on the paper. From various experiments made on wheat under glass, it was found that the weevil retains life longer than any other insect when deprived of air.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, April 21, 1864.

William Sellers, President, in the chair.

John H. Towne, Vice President, } present.
John F. Frazer, Treasurer, }

Washington Jones, Recording Secretary.

The minutes of the last meeting were read and approved.

Letters were read from the Liverpool Literary and Philosophical Society, Liverpool, England; the Literary and Historical Society of Quebec, Canada; and Hon. John D. Watson, Pennsylvania Legislature, Harrisburg, Pennsylvania.

Donations to the Library were received from the Royal Astronomical Society, and the Chemical Society of London; the Literary and Historical Society, Quebec, and the Canadian Institute of Toronto, Canada; H. A. Wise, Esq., U. S. N., Chief of Bureau of Ordnance, Navy Department, Charles Coloné, Esq., and F. Emmerick, Esq., Washington, D. C; the Executive Committee of the Union Relief Association of Baltimore, Md.; James Hall, Esq., Albany, and H. Whitall, Esq., City of New York; Young Men's Mercantile Library Association, Cincinnati, Ohio; Prof. John C. Cresson, Prof. John F. Frazer, H. P. M. Birkinbine, Esq., Dr. Thomas S. Kirkbride, and the Directors of the Girard College, Philadelphia.

Donation to the Cabinet of Models was received from Philip Griffith, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's report for March was read.

The Board of Managers and Standing Committees reported their minutes.

The President reported his letter to the Hon. Secretary of the Navy, transmitting the names of the committee appointed to act on the joint committee on the expansion of steam; also his letters to Hon. Jacob Ridgeway of the Senate, and to Hon. John D. Watson, House of Representatives, Pennsylvania, transmitting the petition of the Institute, asking for amendments to the Charter, which were read.

Candidates for membership in the Institute (7) were proposed, and the candidates proposed at the last meeting (10) were duly elected.

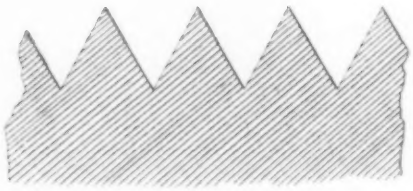
William Sellers, Esq., President of the Institute, read the following paper on a System of Screw Threads and Nuts:

The importance of a uniform system of screw threads and nuts is so generally acknowledged by the engineering profession, that it needs no argument to set forth its advantages; and in offering any plan for their acceptance, it remains only to demonstrate its practicability and its superiority over any of the numerous special proportions now used by the different manufacturers. In this country no organized attempt has as yet been made to establish any system, each manufacturer having adopted whatever his judgment may have dictated as the best, or as most convenient for himself; but the importance of the works now in progress, and the extent to which manufacturing has attained, admonish us that so radical a defect should be allowed to exist no longer. The importance of this subject was long ago recognised in England, and the engineers of that country, by mutual agreement, adopted the proportions now in universal use there. Our standard of length being the same as theirs, it would seem desirable that the system which they have adopted should also be employed by us, unless grave objections can be urged against it and a better one substituted. In examining the details of their system, the first in importance appears to be the pitch or the distance from centre to centre of the threads upon each diameter of screw, which is as follows, viz:

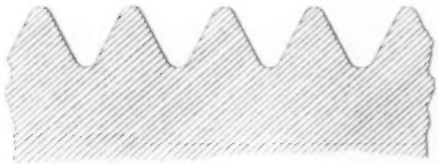
Diameter of screw, . . .	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
No. of threads per inch, .	20	18	16	14	12	11	10	9	8	7	7
Diameter of screw, . . .	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	3 1/4
No. of threads per inch, .	6	6	5	5	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/4
Diameter of screw, . . .	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6
No. of threads per inch, .	3 1/4	3	3	2 7/8	2 7/8	2 3/4	2 3/4	2 5/8	2 5/8	2 1/2	2 1/2

It is probable that this scale, with the exception of the half-inch, would be a fair compromise of all the proportions used in this country.

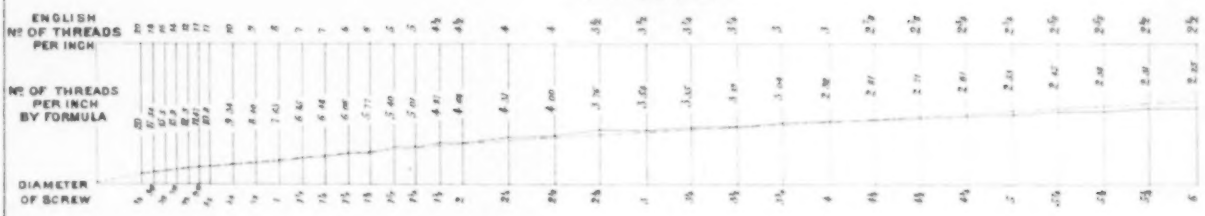
— FIG. 1 —



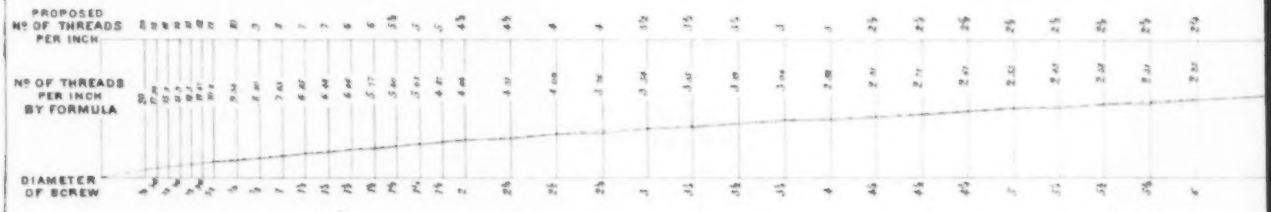
— FIG. 2 —



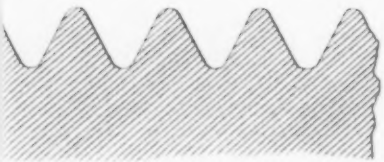
— FIG. 4 —



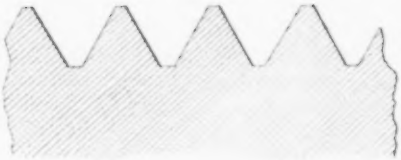
— FIG. 5 —

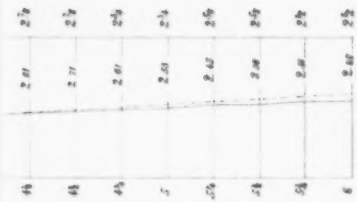


— FIG. 2 —

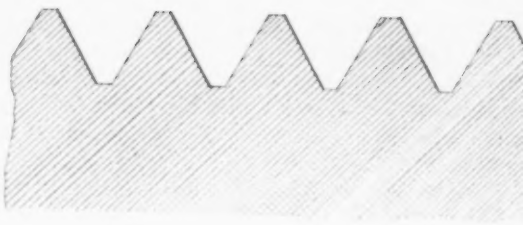


— FIG. 3 —

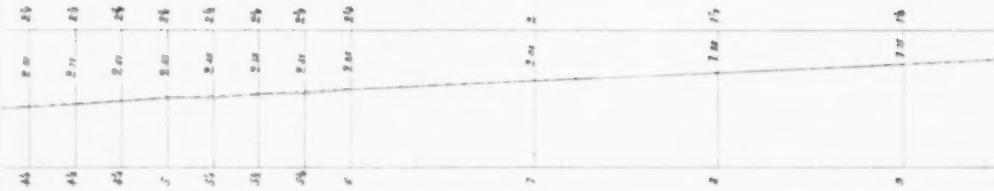


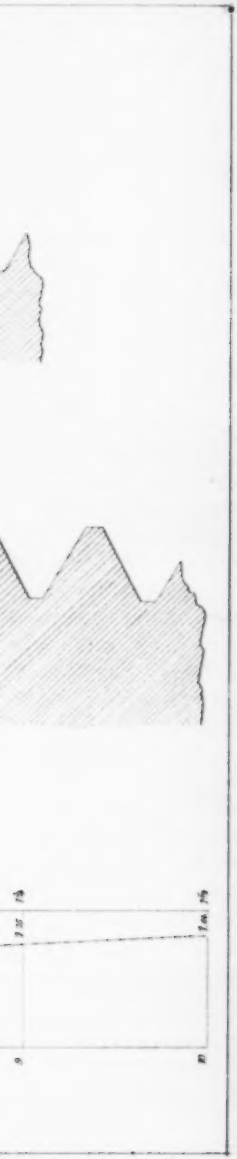


— FIG. 6 —

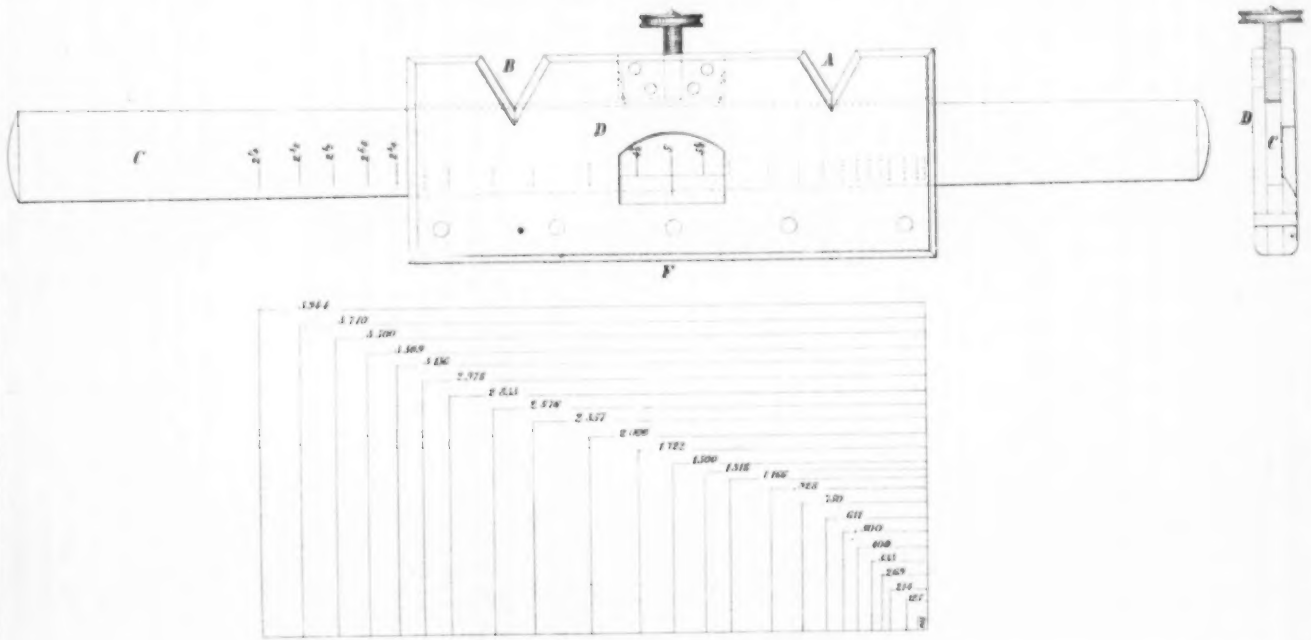


— FIG. 5 —





GAUGE FOR SCREW CUTTING TOOLS.



The accompanying diagram, Plate II. Fig. 4, will serve to show the comparative relation which these pitches bear to each other and to their diameter. This indicates also that the pitch of the half-inch screw is too coarse; our practice would probably average finer. It is interesting to observe the general regularity of the curve produced by these proportions, showing, that notwithstanding they have been determined arbitrarily, they must follow some rule, and we accordingly find that the number of threads per inch may be expressed to the nearest aliquot of an inch by the formula $1 \div \frac{\sqrt{d-a}}{c}$, in which d variable = number of sixteenths of an inch in the diameter of the screw, plus ten, a = constant 2·909, and c = divisor 16·64. The table herewith, calculated to this formula, shows that the English screws, with the exception of six sizes, do not vary from the rule until they reach $4\frac{1}{2}$ inches diameter, and then but slightly. It is believed the pitches as given by the formula would be found an improvement, but not sufficiently so to warrant us in adopting them, providing the other peculiarities of the English system should meet our approval.

Diameter of screw,	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Formula-thread, .	20	17·54	15·5	13·9	12·5	10·8	9·34	8·40	7·63	6·98	6·48
Nearest aliquot, .	20	18	16	14	13	11	10	9	8	7	7
English thread, .	20	18	16	14	12	11	10	9	8	7	7
Diameter of screw,	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
Formula-thread, .	6·06	5·77	5·40	5·11	4·87	4·64	4·31	4·00	3·76	3·54	3·35
Nearest aliquot, .	6	6	$5\frac{1}{2}$	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$
English thread, .	6	6	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$
Diameter of screw,	$3\frac{3}{8}$	$3\frac{1}{2}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
Formula-thread, .	3·19	3·04	2·92	2·81	2·71	2·61	2·53	2·45	2·38	2·31	2·25
Nearest aliquot, .	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{1}{4}$
English thread, .	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$

The form of thread adopted by the English Engineers is one, with flat sides at an angle to each other of 55°, with a rounded top and bottom. The proportions for the rounded top and bottom are obtained by dividing the depth of a sharp thread having sides at an angle of 55°, into six equal parts and within the lines formed by the sides of the thread and the top and bottom dividing lines, inscribing a circle which determines the form of top and bottom of thread, as illustrated by Fig. 2, Plate II. Judging from the practice of this country, the

English form of thread has not met with the same favor that has been accorded to their pitches. Its advantages over the sharp thread are, increased strength to the screw from the absence of acute corners, and the greater security from accidental injury which the rounded top possesses. Its objectionable features are, first, that the angle of 55° is a difficult one to verify; it is probable, no gauges to this angle, made independently of each other and without special tools, would correspond with sufficient accuracy. Secondly, the curve at the top and bottom of the thread of the screw will not fit the corresponding curve in the nut, and the wearing surface on the thread will be thus reduced to the straight sides merely. It is not to be inferred from this that these curves cannot be made to fit, but only that the difficulties in producing contact are so much increased by the peculiar form, that in practice it will not be accomplished. Thirdly, the increased cost and complication of cutting tools required to form this kind of thread in a lathe, it being requisite that this tool shall have at least three cutting sides, in order to form the round top between two of them. The English practice for small work, is to rough out in a slide-lathe with a single-point tool having sides of the proper angle, and finish in a hand lathe with a comb chaser, which has been dressed to the proper form upon a hob kept for that purpose, requiring three kinds of cutters and two lathes to perform what with our practice requires but one cutter and one lathe. On large work, the screw is finished in the slide lathe, with a chasing tool dressed to the proper form upon a hob; and as these hobs are necessarily the standards of form until worn out, it is fair to suppose the shape must be undergoing a continual change. The necessity of guarding the edge of the thread from accidental injury, becomes more and more apparent as the size of the bolt is increased, and we have recognised this by finishing such bolts with a small flat upon the top of the thread; but no plan has been proposed for general adoption upon all screws, nor have any proportions been suggested where a flat is desired, or where from the size of the bolt it would seem to be necessary. As it is very desirable that some uniform rule should be observed in the formation of all threads, and as the sharp top is objectionable upon large screws, this form must be abandoned if we would accomplish our object. It being conceded that the flat angular sides are necessary, we have only to choose between the rounded and flat top; and having examined the former, it only remains to notice whether the flat will be found free from the objections urged against the round. As the sides of the thread are the only parts requiring to be fitted, and as these are of the same shape as the sharp thread, the one will be as easily made as the other. The width of the flat top will be determined by the depth to which the thread is cut, so that the same tool can be used in both cases. The flat on the top of the thread being required to protect it from injury, it is evident a similar shape at the bottom would give increased strength to the bolt as well as improve its appearance. To give this form requires only that the point of the cutting tool shall be taken off and then it is evident this thread can be cut in a lathe with

the same tool and in the same manner as the sharp thread. The width of flat in the bottom of thread being dependent upon the amount taken off the point of the tool, it becomes necessary not only to determine what this amount shall be, but also to provide a means of measuring it. The proportions for the proposed thread and its comparative relation to the sharp and rounded threads, will be readily understood from the accompanying diagrams, Plate II, in which Fig. 1 represents a sharp thread, Fig. 2 a rounded top and bottom to the English proportions, and Fig. 3 the flat top and bottom, all of the same pitch. The angle of the proposed thread is fixed at 60°, the same as the sharp thread, it being more readily obtained than 55°, and more in accordance with the general practice in this country. Divide the pitch, or, which is the same thing, the side of the thread, into eight equal parts, take off one part from the top and fill in one part in the bottom of the thread, then the flat top and bottom will equal one-eighth of the pitch, the wearing surface will be three-quarters of the pitch, and the diameter of screw at bottom of the thread will be expressed by the formula

$$\text{diam.} - \frac{1{\cdot}299}{\text{per in.}}.$$

These proportions will give the depth of the thread almost precisely the same as the English, and as the wearing surface on all screws will be confined practically to the flat sides, we shall find that upon the proposed plan this will be 36 per cent. greater than on the English. The accompanying drawing, Plate III, represents a gauge, designed for measuring the flat upon the chasing tool. D is the main frame of the instrument made in three thicknesses, so that the central pieces may be hardened and ground to shape, the outer pieces serving to keep the central ones in their proper positions. A is an angle of 60° cut in the edge of the frame D, and having its two sides to form equal angles with the edge of the frame. B is similar to A, but having the apex of the angle cut away so as to permit the wedge piece C to pass above the point of junction of the two sides of B. The side of C is graduated, so that upon bringing any particular mark to coincide with a fixed point or mark in the frame D, the edge of C will pass the proper distance above the apex of the angle B, which will indicate the amount to be taken off the point of the chasing tool which has first been accurately fitted to the angle A. In setting the chasing tool in the lathe, the side F of the gauge should be placed against the surface of the work to be cut, which is suspended upon the centres, and while in this position the chasing tool must be adjusted to it and securely fastened. This will insure the thread when cut being perpendicular to the surface. The width of the flat top and bottom may also be obtained by the use of a chasing tool having a flat on its end of known width, but less than required in the bottom of the thread, the depth of the thread having been determined, the tool may cut in to this point and finish by a side movement sufficient to give the required amount of flat.

A system of uniform dimensions for bolt-heads and nuts being intimately connected with the subject just discussed, it is believed that

a convenient formula that would express the required size would go far towards inducing a uniform practice and with this view the following formulæ and tables for screw threads and nuts are offered for the acceptance of our Engineers. Should they meet the approval and be adopted by any considerable portion of the profession, there is every reason to believe they would soon be applied universally, and to enable a comparison to be readily instituted between the systems which have been discussed, diagrams Figs. 5 and 6, Plate II, have been prepared, the former representing the pitch as obtained by the formula, with that proposed to be adopted, and the latter representing a section of a ten inch bolt having its threads to the same proportion. To compare the form of thread, two of the $\frac{7}{8}$ and 2 in taps exhibited are by Whitworth & Co., to the English standard and the other two of same size are to the proposed thread. Formulæ:

Δ = diameter of screws. d = No. of sixteenths plus ten in Δ.

x = pitch of screws. v = No. of threads per in.

a = constant 2·909. c = divisor 16·64.

m = flat top and bottom. n = diameter of screws at bottom.

s = short diam. of nut or bolt-head = $1\frac{1}{2}$ diam. of screws + $\frac{1}{8}$ in.

u = long diam. hexagonal nut or bolt-head.

t = long diam. square nut or bolt-head.

$$x = \frac{\sqrt{d} - a}{c} \qquad v = \frac{1}{x} \qquad t = s \times 1{\cdot}414$$

$$m = \frac{x}{8} \qquad n = \Delta - \frac{1{\cdot}299}{v}$$

$$s = \frac{3\Delta}{2} + \tfrac{1}{8}\text{-in.} \qquad u = s \times 1{\cdot}155$$

PROPORTIONS OF BOLTS AND NUTS.

Diameter of bolt.	Number of threads per inch.	Diameter of root of thread.	Width of flat top, bottom of thread.	Size hole in nut.	Short diameter of hex-nut.	Long diameter of hex-nut.	Long diameter of sq. nut.
$\frac{1}{4}$	20	·185	·0062	·185	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$
$\frac{5}{16}$	18	·240	·0070	·240	$\frac{19}{32}$	$\frac{11}{16}$	$\frac{13}{16}$
$\frac{3}{8}$	16	·294	·0078	·294	$\frac{11}{16}$	$\frac{25}{32}$	$\frac{31}{32}$
$\frac{7}{16}$	14	·344	·0089	·344	$\frac{25}{32}$	$\frac{43}{48}$	$1\frac{1}{16}$
$\frac{1}{2}$	13	·400	·0096	·400	$\frac{7}{8}$	1	$1\frac{1}{4}$
$\frac{9}{16}$	12	·454	·0104	·454	$\frac{31}{32}$	$1\frac{7}{64}$	$1\frac{5}{16}$
$\frac{5}{8}$	11	·507	·0113	·507	$1\frac{1}{16}$	$1\frac{7}{32}$	$1\frac{1}{2}$
$\frac{11}{16}$	10	·620	·0125	·620	$1\frac{1}{4}$	$1\frac{7}{16}$	$1\frac{3}{4}$
$\frac{3}{4}$	9	·731	·0140	·731	$1\frac{7}{16}$	$1\frac{21}{32}$	$2\frac{1}{32}$
1	8	·837	·0156	·837	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{5}{16}$
$1\frac{1}{8}$	7	·940	·0180	·940	$1\frac{13}{16}$	$2\frac{3}{32}$	$2\frac{7}{32}$
$1\frac{1}{4}$	7	1·065	·0180	1·065	2	$2\frac{5}{16}$	$2\frac{27}{32}$
$1\frac{3}{8}$	6	1·160	·0210	1·160	$2\frac{3}{16}$	$2\frac{1}{2}$	$3\frac{1}{16}$
$1\frac{1}{2}$	6	1·284	·0210	1·284	$2\frac{3}{8}$	$2\frac{3}{4}$	$3\frac{3}{8}$
$1\frac{5}{8}$	$5\frac{1}{2}$	1·389	·0227	1·389	$2\frac{9}{16}$	$2\frac{15}{16}$	$3\frac{5}{8}$
$1\frac{3}{4}$	5	1·490	·0250	1·490	$2\frac{3}{4}$	$3\frac{3}{16}$	$3\frac{29}{32}$
$1\frac{7}{8}$	5	1·615	·0250	1·615	$2\frac{15}{16}$	$3\frac{13}{32}$	$4\frac{3}{16}$
2	$4\frac{1}{2}$	1·712	·0280	1·712	$3\frac{1}{8}$	$3\frac{5}{8}$	$4\frac{7}{16}$
$2\frac{1}{4}$	$4\frac{1}{2}$	1·962	·0280	1·962	$3\frac{1}{2}$	$4\frac{1}{16}$	$4\frac{31}{32}$
$2\frac{1}{2}$	4	2·175	·0310	2·175	$3\frac{7}{8}$	$4\frac{1}{2}$	$5\frac{1}{2}$
$2\frac{3}{4}$	4	2·425	·0310	2·425	$4\frac{1}{4}$	$4\frac{29}{32}$	6
3	$3\frac{1}{2}$	2·628	·0357	2·628	$4\frac{5}{8}$	$5\frac{3}{8}$	$6\frac{9}{16}$
$3\frac{1}{4}$	$3\frac{1}{2}$	2·878	·0357	2·878	5	$5\frac{3}{4}$	$7\frac{1}{8}$
$3\frac{1}{2}$	$3\frac{1}{2}$	3·100	·0384	3·100	$5\frac{3}{8}$	$6\frac{7}{64}$	$7\frac{5}{8}$
$3\frac{3}{4}$	3	3·317	·0410	3·317	$5\frac{3}{4}$	$6\frac{5}{8}$	$8\frac{3}{16}$
4	3	3·566	·0410	3·566	$6\frac{1}{8}$	$7\frac{21}{64}$	$8\frac{11}{16}$
$4\frac{1}{4}$	$2\frac{7}{8}$	3·798	·0435	3·825	$6\frac{1}{2}$	$7\frac{1}{2}$	$9\frac{1}{4}$
$4\frac{1}{2}$	$2\frac{3}{4}$	4·027	·0460	4·027	$6\frac{7}{8}$	$7\frac{31}{32}$	$9\frac{3}{4}$
$4\frac{3}{4}$	$2\frac{5}{8}$	4·255	·0480	4·255	$7\frac{1}{4}$	$8\frac{3}{8}$	$10\frac{9}{32}$
5	$2\frac{1}{2}$	4·480	·0500	4·480	$7\frac{5}{8}$	$8\frac{13}{16}$	$10\frac{13}{16}$
$5\frac{1}{4}$	$2\frac{1}{2}$	4·730	·0500	4·730	8	$9\frac{1}{4}$	$11\frac{3}{8}$
$5\frac{1}{2}$	$2\frac{3}{8}$	4·953	·0526	5·053	$8\frac{3}{8}$	$9\frac{11}{16}$	$11\frac{29}{32}$
$5\frac{3}{4}$	$2\frac{3}{8}$	5·203	·0526	5·203	$8\frac{3}{4}$	$10\frac{1}{8}$	$12\frac{7}{16}$
6	$2\frac{1}{4}$	5·423	·0555	5·423	$9\frac{1}{8}$	$10\frac{9}{16}$	$12\frac{9}{10}$

Messrs. Merrick & Sons submitted for examination specimens of a series of screw threads, bolts, and nuts, from 6 inches to $\frac{3}{8}$ths of an inch, as used by them. The pitches of these screws are almost indentical with those proposed in the paper read by Mr. Sellers.

Messrs. Bement & Dougherty submitted drawings of bolts and nuts as used at their establishment (the Industrial Works), with explanatory remarks showing that their pitches of threads were the same as Whitworth's except the half-inch, which is finer (13); and the heads and nuts are invariably hexagonal; the diameter of parallel sides of finished heads and nuts being one-and-a-half times the diameter of the bolts. The thickness of nut equals the diameter of bolt, and the thickness of bolt-head $\frac{7}{8}$ths of the diameter of bolts.

Mr. J. A. Millholland, Master Mechanic and Assistant Superintendent of the Philadelphia and Reading Railroad Company, submitted the following proportions for threads of bolts, and size of bolt-heads as used by that Company.

Reading Railroad Repair Shop, Reading Pennsylvania.

Size of "Tap."	Threads to the Inch.	Size of Bolt-heads.
$\frac{1}{2}$-inch.	12	$\frac{7}{8}$
$\frac{5}{8}$ "	12	$1\frac{1}{8}$
$\frac{3}{4}$ "	10	$1\frac{1}{4}$
$\frac{7}{8}$ "	9	$1\frac{1}{2}$
1 "	9	$1\frac{3}{4}$
$1\frac{1}{8}$ "	8	$1\frac{3}{4}$
$1\frac{1}{4}$ "	8	$1\frac{7}{8}$
$1\frac{3}{8}$ "	7	2
$1\frac{1}{2}$ "	7	$2\frac{1}{4}$

Mr. C. T. Parry expressed a hope that something practical and useful might result from the introduction of the subject of screw threads, beyond the mere reading of the paper, and publishing it in the *Journal*. He said that the want of uniform standard threads has long been felt, and suggested that copies of papers might be sent to the principal engineers of the country, and their opinion solicited with a view of arriving at something acceptable to all parties. He was in favor of finer threads than that used by the English, or the thread proposed in the paper read by Mr. Sellers, particularly for locomotive engine work; but was willing to make concession of opinion for the sake of uniformity. M. W. Baldwin & Co., locomotive builders of this city, with which works he is connected, use on

$\frac{1}{4}$-in.	bolts,	28	threads,	$\frac{3}{4}$-in.	10	threads,	$1\frac{1}{4}$-in.	8	threads,
$\frac{3}{8}$ "	"	22	"	$\frac{7}{8}$ "	10	"	$1\frac{3}{8}$ "	8	"
$\frac{1}{2}$ "	"	16	"	1 "	10	"	$1\frac{1}{2}$ "	8	"
$\frac{5}{8}$ "	"	14	"	$1\frac{1}{8}$ "	10	"			

on all permanent bolts, $1\frac{1}{4}$ inch diameter, they use 10 threads. They

consider 10 threads on $\frac{3}{4}$ bolts coarse, but as they are used principally for stuffing-box glands, and require movable nuts which can be readily run off by the hand, they have adopted this size. They are of the decided opinion, from long experience, that the fine threads are the best adapted for locomotive purposes, as they are more permanently secured when screwed up, than the coarse threads. The threads used by them are abundantly strong to tear asunder the bolt before stripping, and the bolts are much stronger than if coarse threads were used. He was of the opinion that on locomotives especially, all known precautions should be used against accidents that might result from losing bolts, as the machinery, for the most part, is out of sight of the engineer, whilst running over rough roads, which is not the case in stationary machinery; and for this reason they use finer threads, double or jam nuts and through-keys in all bolts, from which by coming loose, accidents might occur. We would be glad to find a coarser thread acceptable, and would be willing to advocate it if by that means only, uniform standard threads could be adopted.

On motion of Mr. J. H. Towne, seconded by Mr. Washington Jones, it was

Resolved, That the Corresponding Secretary of this Institute, be instructed to send a copy of the paper read this evening, on screw threads and nuts, to the American Institute, New York, and to other similar societies, with the request that they will give it an early consideration with a view to promote the introduction into general use of the system advocated, if they shall approve of the same.

On motion of Mr. Algernon Roberts, seconded by Mr. C. T. Parry, it was

Resolved, That the following gentlemen be a committee to investigate the question of a proper system of screw threads, bolt-heads, and nuts, to be recommended by this Institute, for the general adoption by American engineers.

Committee.—W. B. Bement, C. T. Parry, J. V. Merrick, J. H. Towne, C. Sellers, B. H. Bartol, Edw. Longstreth, Jas. Moore, and J. W. Murphy.

Mr. E. Longstreth exhibited an instrument for setting the tools of screw-cutting lathes, so as to bring the point of the tool at right angles with the surface to be cut. It consists of a piece of steel one-and-a-half inches long, with a groove front which is laid against the bar; on the back, and at right angles with the groove, is a notch to receive the tool point.

Mr. L., also exhibited an instrument for testing the correctness of screw threads.

Mr. Chase read the following conclusion of the abstracts of his papers on "Tides of Rotation."

On account of the mutual dependence of all the forces of nature, and the reasonableness of Prof. Faraday's conjecture, that they are often,

if not always, convertible more or less into each other,* it seems probable that the disturbances of the magnetic needle may be as closely connected with the earth's rotation, and the continually changing position of each point relatively to the sun, as those of the barometer and thermometer. Ampère held that the earth is an electro-magnet, magnetized by an electric current from east to west, the current being excited by the action of the sun's heat successively on different parts of the earth's surface as it revolves toward the east. The friction of trade-winds and ocean-currents and the variations of light and temperature that are produced by rotation and orbital revolution, must exert an influence upon the magnetic needle, and besides these indirect effects, M. Arago showed that simple rotation, in some unknown way, produces magnetism in bodies of every description. Many have supposed that this magnetism is derived from the earth by induction, but on account of the impossibility of escaping from the influence of terrestrial magnetism, it is difficult to obtain any conclusive evidence on the subject.† A similar impossibility has interfered with Prof. Faraday's endeavors to connect gravity and magnetic or electric action by experimental results. The probability of such a connexion has been shown by the electricity developed in the dry pile of De Luc, and by Gen. Sabine's observation, that when the sun and moon were on the meridian, the magnetic variation reached 5°, but when they were in quadrature, it fell as low as 20′.‡

The great forces of nature can be measured only by their disturbances or their deviations from uniformity. The action of gravity is so nearly uniform at all times and in all parts of the globe, that it is difficult to imagine any crucial experiment that could demonstrate its relations to magnetism. Perhaps a needle, hinged at its point of support, with the two extremities nicely balanced, might help us towards such a demonstration, if careful experiments were tried, to show the relative influence of gravity upon each extremity, both before and after magnetizing, and when subjected to artificial magnetism, so as to produce various amounts of deviation from the normal dip and declination. Or, centrifugal force, so applied as alternately to assist and oppose the effects of gravity, as in large fly-wheels revolving with various degrees of rapidity, may indicate variations of magnetic influence, that can be explained only by the conversion of gravity into magnetism or the reverse.

Prof. Faraday, in a lecture before the Royal Institution in the year 1857, endeavored to show that our usual conception of gravity is not in harmony with the principle of "conservation of force." Prof. Brücke§ and others, have tried to remove the difficulties in which the question is involved, but I believe none of the proposed solutions have been satisfactory to the learned philosopher who first started the discussion.

* Phil. Mag., Fourth Series, 1, 68.

† See correspondence of M. J. Nickles, Silliman's Journal, v. xvii. p. 117, &c.

‡ Silliman's Journal, v. xix p. 424.

§ Phil. Mag., Fourth Series, 15, 81.

It has even been questioned whether gravity can be properly called a force, or whether it is anything more than a simple "tendency." Prof. Brücke has shown conclusively, that it is subject, like heat and other recognised forces, to all the laws which regulate the interchange of *actual* and *potential* energy, and our barometrical investigations furnish a beautiful illustration of the manner in which its tension is balanced by opposing forces.

We speak, indeed, of weight, as if it could be predicated only of bodies at rest, and as if it were so entirely distinct from momentum that no comparison could be properly instituted between the two. Precisely the reverse is true. Absolute rest is apparently an impossible condition of matter, for, to whatever extent the action of opposing forces may be relatively neutralized, the inconceivable rapidity of æthereal, planetary, and stellar motions, produces a constant change of place. Even if we confine our attention to the earth alone, in each instant (dt), every particle has a tangential motion (tan. $d\theta$), and a central motion of gravity (sin. $d^2\theta$) that constitutes a *vis viva* which we call its weight, and which is in equilibrium with the elasticity of the molecular æther. The sum of all the instantaneous energies is the same, whether the particle fall freely for any given time, or remain apparently at rest. All the potential energy which is transformed in one case into the actual energy of motion,* in the other is counteracted by an equivalent and opposite central energy of elasticity. Therefore, when we compare the relative effects of rotation and gravity, it is immaterial whether we use as the measure of force, the integral of the *vires vivae*, or the respective amounts of motion that the two forces would produce, if they were able to act freely for the same time. The difficulty of determining the repulsion of molecular elasticity precluding any satisfactory use of the former measure, I employed the other, and the precise accordance of the results thus obtained, with the results of observation, justified the correctness of the hypothesis, in the same manner as the accurate computation of planetary motions has confirmed the Newtonian theory of gravity.

Gravity, therefore, with the same propriety as heat, may be considered as a "mode of motion," whether acting merely as "dead weight," or as an accelerating or a deflecting force. If it can be shown that magnetism also originates in motion, we may be able to demonstrate the mutual convertibility that Faraday suspected.

The earliest hypothesis with regard to terrestrial magnetism looked

* The potential energy of gravity is represented by $g = 32$ ft. per second. The earth's rotation allowing only about $\frac{1}{289}$ of this amount, or ·1107 ft. per second, to be converted into actual energy, the remainder must be employed in overcoming molecular elasticity. The formula $a = \left(\frac{g t^2 r^2}{4 \pi^2}\right)^{\frac{1}{3}}$ gives 26,221 miles as the radius of the sphere of attraction that is in equilibrium with the molecular elasticity at the earth's surface. These opposing forces must produce constant oscillations, and by the study of these oscillations, it may perhaps be possible to reconcile the several hypotheses of Newton, Faraday, Mossotti, and Challis, respecting the nature of gravitation. See Phil. Mag., Fourth Series, v. xiii. p 231-7, and v. xviii. p. 447, *sqq.*

for its cause to a powerful magnet, lying nearly in the line of the earth's axis. Subsequent discoveries led to a modification of this view by the supposition of another magnet, pointing towards the Siberian pole. Mr. Barlow's idea, that the magnetism is superficial and induced,* has now been generally adopted, and if it could be shown that solar or rotary action is capable of developing magnetism in particles such as those which are known to constitute our globe, the great difficulty in the way of satisfactory explanation would be removed.† Ampère's, Barlow's, and Christie's experiments showed that simple rotation is sufficient to affect the magnetism of a compass-needle,‡ and in the oxygen of the atmosphere, which, as Faraday discovered, has a specific magnetism, variously estimated at from $\frac{1}{88}$§ to $\frac{1}{287}$‖ of that of iron, we have a medium through which any induced magnetism may be distributed over the entire surface of the earth. Some simple experiments that can be easily repeated, seem to confirm Ampère's views, and to indicate the manner in which the circulating electric current is excited.

There is a species of mechanical polarity, of which I have never seen any notice, that is apparently produced by motions, resembling those to which the air is continually subjected. It may be exhibited in the following ways:

1. In the middle of a basin of water, lay a long strip of any substance (floating it by corks or otherwise, if it is heavier than water). After the water has become still, lift the basin carefully by one hand, and hold it at arm's length. The intermitting muscular action produces longitudinal vibrations, which tend to bring the floating strip into a line with the outstretched arm, and the tendency may be increased by moving the basin gently up and down.

2. Hold the gimbals of a binnacle compass so that it can swing only in one direction, and cause it to move like a pendulum in that direction. The needle will tend towards the line of oscillation. Vessels may have been lost from ignorance of this fact, for it is not unusual for compass pivots to become so worn that the needle moves sluggishly, and in order to start it, the compass box is shaken. If one of the gimbal hinges should be rusty, the shaking would bring the needle into a line perpendicular to the axis of the free gimbal, and the captain might easily suppose that he was sailing north, when his course was due east or west.

3. Take an ordinary pocket compass, grasp it firmly between the thumb and finger of one hand, and move it quickly up and down through a small arc. The needle, as in the last instance, will tend towards the plane of motion. This experiment may be variously modified, according to the length and directive energy of the needle, the steadiness of the operator's nerves, &c. Sometimes a simple grasp, with a powerful

* Phil Trans., 1831.

† Enc. Brit., Art. "Magnetism."

‡ The effect of rotation on the magnetic needle may be shown in a rough way, by causing an ordinary grindstone to revolve rapidly, and bringing a compass near its edge.

§ By M. Becquerel. ‖ M. Plücker.

muscular contraction, will bring the needle into line, without any other vibration than that which arises from the irresistible nervous tremor. Sometimes the momentum acquired by each pole in its approach to the operator, carries it forward so as to bring the other pole under the wave-influence, and the needle is thus made to rotate so rapidly as to become nearly invisible.

The polarity in each of the three cases here enumerated, is easily explained upon purely mechanical principles, but there are some indications that seem to show a close connexion between the mechanical vibrations and those of nervous electricity. There appears to be a great difference in the control of different individuals over the needle. Some can bring it into line at once, with scarcely any perceptible motion, while others are obliged to use considerable effort; the needle does not seem at all times equally susceptible; it often appears more easy to produce rotation in one direction, than in the other. There may, therefore, be a natural connexion between these experiments and those of M. Du Bois Raymond, who attached two strips of platinum to a very delicate galvanometer, and caused them to dip into two cups of salt water. Dipping the fingers of each hand into the cups, and alternately bracing the muscles of each arm, he produced a perceptible deflection of the needle. MM. Becquerel and Despretz repeated the experiment without obtaining very satisfactory results, but M. Humboldt was more successful.* Add to these phenomena the well-known evidences of a constant current, circulating around magnets, and if we suppose that electricity consists simply of vibrations, it will seem perfectly natural that the magnet should obey the strongest vibrations.

The combined effect of solar action, trade-winds, and prevailing aerial currents, in producing mechanical polarized vibrations that must influence the magnetic needle, was illustrated by diagrams.

Mr. John W. Nystrom, Civ. Eng. made the following remarks:—
On Metrology and Arithmetic.

As this is a subject which has occupied my attention for many years, and cost me much time and money, I was very glad to hear at the meeting in February, that the Franklin Institute appointed a Committee on Weights, Measures, and Coins, and that the honor was conferred on me, of being one of its members.

It was my desire to take an active part in the proceedings of that Committee, but early in March, business called me to the Northern States and I had only the pleasure to attend the first two meetings, which afforded me the greatest interest, not that I expected we would come to any satisfactory conclusion on metrology, or that we could accomplish in one month what has puzzled our ancesters for centuries.

The International Decimal Association has, for the last ten years, labored very hard on that subject, and, as yet, accomplished comparatively nothing; and if proper precaution be not taken, our result will likely be the same.

It is not reasonable to suppose that only a few members represent-

* See Silliman's Journal, v. viii.

ing only one branch of the Arts, (as was the case in the last meeting I had the pleasure to attend,) would be able to accomplish an object of such paramount magnitude and destination.

The object of our Committee ought to be, to devise a system of metrology that would in all its bearings fulfil all the requirements of the nation, or of mankind. In the accomplishment of this, members must necessarily represent all the different Arts and Sciences; as Astronomy Navigation, Geography, Geology, Chemistry, Pharmacy; and in the Arts, the different branches of the Mechanics, as Shipbuilders, Marine-Engine builders, Locomotive builders, Tool-makers, Bridge builders, Surveyors, Architects, &c. And in the Trade, ought to be represented the Market, Custom-House, Bankers, &c., &c.

In case we have not members of the Institute to represent all these different Arts and Sciences, I would propose to invite "outside representatives."

The Committee should consist of at least twenty or thirty members, and constitute a standing committee of metrology until the object is accomplished.

Philadelphia (a City of nearly a million inhabitants,) ought to be able to furnish the requisite materials for this subject, so highly important to our nation, and it is our most solemn duty to give the subject our serious attention, in hope of removing one of the heaviest burdens ever instituted on mankind.

This is not easily accomplished, and should not be hurried. We know what inconveniences it causes, and how little we are disposed to change old habits, and when we shall come to see and recognise the necessity of a change in metrology, we ought to take care not to expose our generation to an unremunerative inconvenience, to be abolished by their descendants.

In the two meetings on Weights and Measures, which I had the pleasure to attend, the Committee appeared to incline to the decimal system, and I believe it was proposed to decimate our old units. The French metrical system was also spoken of, but did not seem to gain much favor.

I have, on former occasions, alluded to the imperfection and inconveniences attending the decimal system, and proposed as a substitute, a binary system of arithmetic and metrology, fully described in the Journal of the Franklin Institute.

The subject is of such great importance that I do not hesitate to allude to it again. We know our ancestors have been laboring on this great problem for centuries, and it is my own conviction that we are not better off to-day in metrology, than they were in the middle ages; for the little benefit derived from the decimal system in book-keeping does not compensate the inconveniences it causes by depriving the people of their natural conception in counting.

As long as we confine ourselves to decimals, we have nature against us, or rather, we are struggling against nature.

I am at present engaged in working out a new system of construct-

ing ships, where I am at liberty to arrange it according to any system I please; but the decimal system is the very last I would adopt. I have now arranged it into a binary or octonal system, and that, mind, when I am obliged to employ decimal arithmetic. In working out the tables I have over one hundred thousand multiplications to make, each of five figures by seven. I cannot beneficially employ logarithms, because it is the logarithms themselves to be multiplied, and they do not extend to the requisite number of figures.

A binary arithmetic would reduce that immense labor to only about one-fifth. The case is the same with all decimal calculations. Will you then wonder that I advocate a binary arithmetic?

I am well convinced that life and property are constantly wasted; our comfort and progress considerbly retarded, for the want of a natural system of counting.

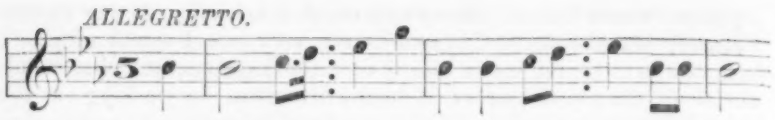
The decimal arithmetic must be pumped into us, by the routine of schooling, and those who have not the opportunity of such education, are left to the mercy of consequences, while a binary system would come natural to us like music.

Our mental conception of decimal arithmetic is restricted to a very narrow limit,—most simple examples must be set down on paper, and even then may be troublesome in the solution; while a binary arithmetic would, in most cases, dispense with the mechanical operations in calculations; difficult examples of which we have now no conception, could be managed mentally like that of a musician who plays a difficult piece of music by the ear.

There is a very striking resemblance between arithmetic and music, the latter we know is arranged by nature in a perfect binary system, which can be managed by a child before it can read or even before it can count to 10. If music was arranged in decimals, it would be as difficult to learn as our present arithmetic, and we could not catch up a song by the ear.

We have some very faint indications of attempts having been made to arrange music into decimals. Mr. Wm. H. Fry, who lectured on music in this city some years ago, said, "Five-beat time is scarcely ever used, and then only for crazy chorus, or to produce pandemonic effects," and such is the case with the decimal arithmetic; it produces a pandemonic effect on mankind.

I know of only one case on record of decimal music, namely the tenor solo in the second act of the opera "La Dame Blanche," composed by Boieldieu, late Professor of Composition in the Concervatoire of Music, Paris. Professor Boieldieu was a Scientific man. He evidently attempted to try the decimal system of music, and succeeded only to arrange a five-beat bar,—but the subdivision of the beats, as well as of the burdens, are still binary as required by nature.

I beg to detain you a few minutes more, by illustrating this music on the black-board, to explain how unnatural the decimal system is to the mind.

This is the five-beat bar *invented* by Prof. Boieldieu. When it was first produced in Paris, some 40 years ago, the musicians in the audience, in which Doctor Meignon now of this city, was present, failed to make out what it was. When the musicians first tried it in rehearsal, they broke down in the middle of it, with no little amusement, and it was found necessary to sub-divide the bars into two parts, making three beats it the first, and two in the second as shown by the dots, which is the form in which that music now appears in the market. This shows how unnatural it is to the mind to divide by five.

I cannot bring to my recollection any rule in geometry by which to divide a straight line into five or ten equal parts, except by the aid of projection; and if there is such a rule it cannot be simple, but complicated like the decimal system.

Music is employed to lubricate our movements and feelings, like oil in machinery. We use music to dance by, to march by; and we use music in hauling and hoisting. Should decimal music be started in a ball-room, the dancer would find himself obliged to lead the bars sometimes with his right and sometimes with his left foot, and could not possibly come right at the end of the burden, which would surely cause confusion. If decimal music should be drummed for a marching regiment, the soldiers would surely step on one another's heels. I would not trust to such music in hoisting a boiler on board a steamboat, for it would operate the same as if a horse would attempt to take three steps with his fore feet, while two with his hind feet; and in like manner does the decimal system operate in almost every transaction in our retail dealings.

The other day I went to Germantown, bought two tickets at the railway station, the price of each was

	Decimal.	Binary.
	12 cents	2
Paid with	50 "	8
Received in change	25+1 "	4

which is a very common, but odd transaction.

Let us now see what it would be with a binary system. The dollar divided into halves and halves, say into 16 parts, when 50 cents would be represented by 8 which is half of 16, the price by 2, and the change by 4. Here you will find that the binary system not only gives the simplest and smallest numbers for our mental conception, but we would have coins to suit it exactly.

I have here a bill of amusement which says, "Panorama of the Bible."

	Decimal.	Binary.
Commences at	7½ P.M.	5
Matinees,	3	2
Admittance,	25 cents.	4
Children half-price,	15 cents.	2

you see it is all odd and wrong for children.

A binary system will give an even hour for 7½ o'clock, because $7\frac{1}{2} : 24 = 5 : 16$.

The binary column you see contains the most simple figures, with the desired price for children.

I shall not detain you any longer by pointing out cases of these endless inconveniences, which we are so accustomed to, that we seldom notice them, but by some reflections we find it in every transaction. The even and easy numbers for counting, such as 2, 4, 6, 8, 12, 16, 24, 32, &c., must, by the decimal system, be piled up by odd coins and measures.

These inconveniences are more conspicuously noticed by me, on account of having paid attention to the subject for a great many years, and practiced a binary system of arithmetic.

In chemistry we know that the elementary substances combine in binary proportions.

The binary theory in chemical compounds is a very recent discovery. If we had had a binary arithmetic, it is very likely that that important discovery would have been made long before. Another discovery of equal, or perhaps of greater importance, yet to be made, is the physical constitution of heat. The road to that discovery is indicated by the numbers representing the different properties of matter, as specific and latent heat, smelting and boiling point, conducting power for heat, specific gravity, atomic weight, cohesive strength, &c., &c., all of which appear to have some binary relation to one another, but their decimal numbers only present a heap of incongruous figures to the mind.

It shows, however, how weak we are, when we unnecessarily allow ourselves to drag this heavy burden along with us; and the more that it is propagated and advertized in most of the scientific journals of the day. European journals often devote their pages and columns to the decimal system, unconsciously extolling and expatiating on its merit.

I am not afraid, or do not hesitate to advocate a binary system of arithmetic and metrology.—I know I have nature on my side,—if I do not succeed to impress upon you its utility and great importance to mankind, it will reflect that much less credit upon our generation, upon our scientific men and philosophers.